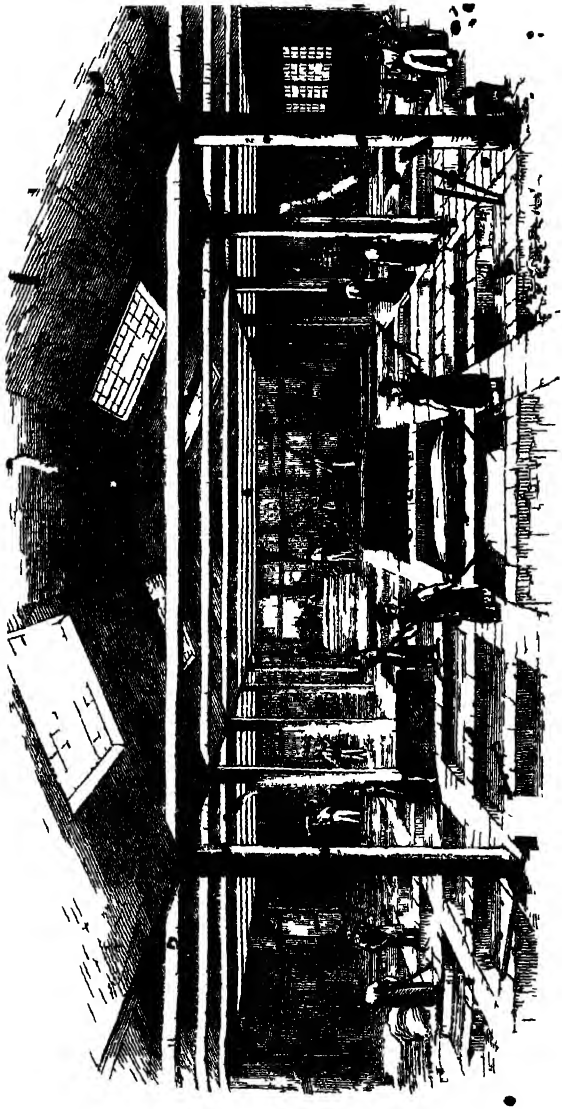
The Useful Arts

And

Manufactures Of

Great Britain



THE USEFUL ARTS AND MANUFACTURES OF GREAT BRITAIN.

THE MANUFACTURE OF LEATHER.

THE manufacture of leather in this country ranks next in importance to that of cotton, and of wool; and is, perhaps, equal to that of iron. Nor need this excite surprise, for what substitute could be found for leather?—a substance at once durable and elastic; affording protection from wet, from cold, and from external injury; capable of being formed into innumerable useful articles, and susceptible of a high degree of ornament; entering into the structure of various engines and machines; supplying harness to our horses, linings to our carriages, and covers to our books. But the chief importance of leather arises from its value as an article of clothing; and the necessity for such a protection seems to have stimulated man in all ages, and in the most widely separated parts of the globe, to the invention of some method for preserving the skins of animals.

Hence, it is difficult to say anything respecting the origin of an art, which, being so necessary to the comfort and welfare of mankind, must have been practised at a very early period. The skins of beasts taken in the chase are, in their fresh state, tough, flexible, and elastic, and seem well adapted for clothing; but in drying they shrink, become horny, and are liable to putrefy by exposure to moisture. But the qualities of the skin, which adapt it to

admirably to the purposes of clothing, may be restored, and even rendered permanent, by placing it in solutions of certain vegetables which abound in almost every country. Skins may also be made incorruptible, by steeping them in mineral waters which contain iron or copper; and the same purpose is answered by rubbing in oil or fat, a practice which is clearly alluded to by Homer.

The object of these processes being to render soft and flexible, that which would otherwise be hard and unyielding, the skin thus transformed was called by our Saxon ancestors *lith, lithe,* or *lither,* (that is, soft, yielding,) from which the word *leather* is supposed to have been derived. The word to *tan,* and the French *tanner,* are from the low Latin, *tanare.*

VARIETIES OF SKINS USED IN TANNING.

LEATHER is prepared from the skins of animals by means of a peculiar vegetable substance, found in the bark of most trees, called *tannin.* It is also made by a preparation of alum and salt, as in the process of *tawing;* a third method is, by dressing in oil.

The skin or hide of an animal consists of three distinct parts placed one over the other:—1st, the *epidermis,* or cuticle, which is covered with hair or wool; 2d, the *reticulated,* or *net*-like *tissue;* and 3d, the *dermis,* or true skin, which is in contact with the flesh. This last is the only part which can be tanned; so that it is necessary to get rid of the two former before the process of making leather can be commenced. The true skin is a thick, dense, hard membrane, composed of fibres interlacing each other in a curious complex manner. It is not equally thick throughout its texture; the part which covers the mane, the back, and the rump, being much thicker than the parts covering the belly. This skin consists, chiefly, of a substance called *gelatine,* from its jelly-like appearance when in solution: it is an abundant

material in many animal matters; in the skin of the ox it is *indurated*, that is, hard. Gelatine is distinguished from albumen (of which the white of an egg chiefly consists,) by being easily dissolved in warm water; whereas albumen is made solid by heat. All animal matter which affords gelatine may be used in making glue.

It might be supposed, in consequence of the vast quantity of animal food consumed in England, that the shambles would afford an abundant supply of skins to the tan-yard; but the hides furnished by this country are by no means sufficient in quantity to meet the demands of the leather trade. Immense quantities of skins are annually imported from various parts of the world, and it may be interesting to notice, briefly, their varieties and sources.

All tanned leather is classed and known under two denominations, *hides* and *skins*. From these there are three kinds of leather tanned in England.

I. *Butts*, or *backs;* these are selected from the stoutest and heaviest ox-hides. The butt is formed by cutting off the skin of the head for glue, also the neck, the shanks, and a strip of the belly, on each side. The remaining central part, the *butt*, or *back* of the hide, is the thickest part, and is used for purposes where great strength is required.

II. *Hides*, or *crop-hides*, consist of cow-hides, or the lighter ox-hides; they are tanned whole, and form leather which is used for ordinary purposes.

III. *Skins* are used for all the lighter kinds of leather, as will be more particularly noticed in the following enumeration.

The hides of South America are in the highest repute; they are the produce of the half-wild cattle which pasture on the wide plains between Buenos Ayres and the Andes; hides are also imported from various parts of the continent, and also from Morocco, the Cape of Good Hope, &c. In the year 1829,*

* In the year 1830 the duty on leather was wholly repealed.

286,416 cwt. of hides were imported; of which 166,400 came from South America, 24,000 from North America, and the remaining 66,000 from Russia, Denmark, Germany, and the Netherlands.

The *butt*, or *back*, of the ox-hide forms the stoutest and heaviest leather, and is used for the soles of boots and shoes, for most parts of harness and saddlery, for leather trunks and buckets, hose for fire-engines, pump valves, soldiers' belts, and gloves for cavalry. Formerly, when the use of metallic armour was on the decline, its place was taken by a very thick pliant leather made from the hide of the urus, or wild-bull, at that time plentiful in the forests of Poland, Hungary, and some parts of Russia. This animal was commonly called the *buffe*, whence originated the term buff-leather. The Russian Company, chartered by Henry VIII., was obliged to import a certain number of buffe-hides, to be manufactured for military purposes. Real buff-leather was pistol-proof, and would turn the edge of a sword. During the civil wars, in the reign of Charles I., it was in great request, but it afterwards declined. The hides of the real buffalo of Italy were also imported for the same purpose; but the modern buff-leather is made from cow-hide, and is used for little else than soldiers' belts.

Bull-hide is thicker, stronger, and coarser in its grain than that of the *cow*. The hide of the *bullock* is intermediate between the two. *Calves' skin* is thinner than cows', but thicker than most other skins employed. Leather is prepared from it for the bookbinder, by the process of tawing; but the greater part of the supply is tanned, and then curried for the upper parts of shoes and boots.

Sheep-skins are supplied, chiefly, by the home markets, but many thousands are imported from the Cape of Good Hope, and are considered superior to those of England, from which they are easily distinguished by the greater width of the skin that covers the tail. They are simply tanned, and em-

ployed for various purposes for which a thin cheap leather is required; such as for common book-binding, leathering for bellows, whip-lashes, bags, aprons, &c. They also form the cheaper kinds of wash-leather, for breeches, gloves, and under-waistcoats; as also coloured and dyed leathers, and mock morocco used for women's shoes, for covering writing tables, stools, chairs, and sofas, lining carriages, &c.

Lamb-skins are also, chiefly, of home produce; but they are largely imported from the North of Italy and Sicily. They are dressed white, or coloured for gloves. In 1829, 1,497,000 lamb-skins were imported from Italy and Sicily, and 239,000 from Spain.

The skins of *goats* and *kids* form the best kinds of light leather. The great supply of the best kid-skins is from Switzerland and Tuscany, whence they are shipped chiefly at Leghorn. Goat-skins are principally obtained from the coast of Barbary and the Cape of Good Hope. They form the best dyed morocco of all colours. Kid-skins supply the finest white and coloured leather, for gloves and ladies' shoes. In 1829, 306,000 goat, and 106,000 kid-skins were imported. Of the former, 104,000 came from Barbary, 87,000 from the Cape of Good Hope, and 36,000 from France; and of the latter, 82,000 from the Italian ports, and 16,000 from Spain.

Deer-skins are, to some extent, supplied by our parks; but the principal supply is from New York and New Orleans; a few are sent from Canada, and some from India. *Antelope-skins* from the Cape of Good Hope are of good quality. In 1829, 120,000 deer-skins were sent from the United States, 1,780 from Canada, and 675 from India. They are all shamoyed, or dressed in oil, chiefly for riding breeches.

Shamoyed leather of sheep, goat, and deer-skins, was formerly a celebrated and lucrative branch of the leather trade in this country. It was employed chiefly for the breeches, white or dyed, worn

persons who rode muck on horseback. The English shamoyed leather was so excellent that it was not only worn by our own troops, but by the cavalry of Prussia, Austria, and most other German states. During the Peninsular war, however, it was discovered by the British commander that, in wet weather, the leathern garments fitted close to the skin, and, being longer in drying, chilled the men, and made them liable to rheumatic and other complaints. Woollen cloth was therefore substituted, and the example being speedily followed by Austria and Prussia, this branch of the leather trade speedily declined.

Horse-hide is used, to a limited extent. It is tanned and curried for harness work for collars; and, being pared thin, is now much used for ladies' walking-shoes.

Dog-skin is thin, but tough, and makes good leather. The supply is entirely limited to this country, but has much fallen off of late years, being superseded as a material for thin dress-shoes by horse-leather, and tanned rat-skins. *Seal-skin* is inferior to that of the dog, but is employed for similar purposes. In 1829, 289,500 seal-skins were imported, the greater part of which were from Canada; but a large proportion of this supply is used as fur in covering caps.

Hog-skin furnishes a thin, dense leather, employed entirely for covering the seats of saddles. The general custom of cooking pork with the skin on, greatly limits the supply, which is chiefly from Scotland and Yorkshire.

VEGETABLE SUBSTANCES USED IN TANNING.

In the bark of most trees there resides a peculiar and remarkable substance, to which the name of *tannin* has been applied, from the circumstance of its uniting with the gelatine of skins, and thus

forming leather. The process by which tannin is obtained from vegetable substances need not be detailed, because the tanner never has to obtain it pure and separate from the woody fibres, &c., such process belonging to the scientific chemist. It will, however, be interesting to state the various proportions in which tannin exists in different vegetable substances, as ascertained by Sir Humphry Davy. In every 480 parts of each of the following substances, there exists a quantity of tannin, as shewn in the second column:—

White inner bark of Old Oak	72 parts.
— — — Young Oak	77
— — — Spanish Chestnut	63
— — — Leicester Willow	79
Middle bark of Oak	19
— — Spanish Chestnut	14
— — Leicester Willow	16
Entire bark of Oak	29
— — Spanish Chestnut	21
— — Leicester Willow	33
— — Elm	13
— — Common Willow	11
Sicilian Sumach	78
Souchong Tea	48
Green Tea	41
Bombay Caoutchouc	261
Bengal ditto	231
Nut Galls	127

Thus it will be seen how greatly the quantity of tannin varies in different vegetable products; and that it is by no means indispensable to employ oak in preference to any other vegetable bark; but the advantages of cheapness and abundance cause it to be generally preferred to other substances in the tanning of thick leather; although in some tan-yards, where other kinds of bark can be more profitably procured, they are preferred to oak. Most tanners, however, state that oak-bark surpasses all other barks in producing durable leather. The price of rough oak-bark varies from *5l.* to *7l.* per ton; but when freed from moss and the external core, the price becomes

as much as 9*l.* per ton. Large quantities of oak-bark are imported from the continent, but the quality is not equal to that of the English.

Of late years the bark of the larch has been much used in tanning. Large quantities of *valonia* and *terra japonica*, or catechu, and also a bean-pod called *divi-divi*, have been imported, and recently the bramble and hop-bine have been used for the same purpose. Valonia produces a leather of great solidity and weight, and of a greyish colour, with much bloom on the surface. It is said to resist water better than leather made from oak-bark, which is of a light fawn colour. Leather made from terra japonica is of a dark fawn colour, inclining to red; it is light and spungy, and not waterproof. In the preparation of thin leathers *sumach* is largely employed.

PREPARATION OF THICK LEATHER.

We will now visit the tan-yard, and trace the process of a skin from its raw or *green* state, until it is converted into leather.

When hides are received fresh from the slaughter-house, they are first washed in a stream of water; the horns are then removed and sold to the comb-makers; the ears and other projecting portions are cut off and sold to the glue-maker. Imported skins, which have been either salted or thoroughly dried for the purpose of preservation, require soaking in water for about ten or fourteen days.

The next operation is to get rid of the hair and scarf skin, for which purpose the hides are placed in oblong troughs or pits, containing lime mixed with water. In the course of several days the lime dissolves the hair sheath, and combines with the fat of the hide to form a kind of soap, which is easily washed off.

LIME PITS.—UNHAIRING HIDES.

When it is found that the hair can be removed, the *beam-man* places the skin upon a cylindrical table called the *beam*, and by means of a large two-handled knife scrapes off the hair, leaving what is called the *grain* of the skin. The hair is sold to the plasterer for mixing up with mortar.

The skin being once more washed, it is *fleshed;* that is, the beam-man passes a flesh-knife over the inner surface, for the purpose of getting rid of the cellular tissue and any remaining portions of fat or flesh.

The next process is that of *abating*, or *grainering*. The skins are put into a pit with a solution of dogs' dung; but if this is not to be had in sufficient quantity, its place is supplied by pigeons' dung, or by that of domestic poultry, or of sea birds. The excess of lime is removed by the lithic acid of the dung; and the ammonia formed by the putrefaction of the mixture forms a soap with any remaining fat of the hide. The skin also becomes thinner by a portion of the gelatine being dissolved, and if left too long

in the mixture it would be reduced to a tender jelly-like mass: hence considerable care and judgment are required in regulating this part of the process.

The skins are now again worked on the beam, in order to get rid of all slime, dirt, &c., and are afterwards immersed for twelve hours in a very weak solution of sulphuric acid, called *sours*, for the purpose of *raising* or thickening the skin; the only use of this process, according to some, is to make the leather look thick when completed; but it probably assists the entrance of the tan into the pores of the skin, and may thus produce better leather, and shorten the process of tanning.

All these preparatory processes being completed, the actual tanning now commences. The tan-yard generally occupies a large extent of ground, and above it are lofts for drying the leather when it is tanned. The tan-pits* are formed in the earth, and lined with deal planks; they are oblong in shape, and from six to eight feet in depth. They are ranged in rows side by side, a space being left between them for the convenience of the workmen. The oak-bark is ground by a mill, attached to the yard, and the solution of bark, called *ooze*, is prepared in pits expressly reserved for the purpose. From these pits it is drained off into an ooze-well, whence it is pumped into shoots, and conveyed to any part of the yard. Since ooze of various degrees of strength is required, it is sometimes usual to employ a kind of hydrometer, called a *barkometer*, for measuring it. The instrument is graduated by the standard of pure water, and the ooze is said to be strong or weak, according as it rises above or sinks below the water-mark. But these indications are not always to be depended on, since the ooze dissolves a portion of the gelatine of the skin, and would hence appear to be strong when the tannin had been almost entirely exhausted. The more usual test of

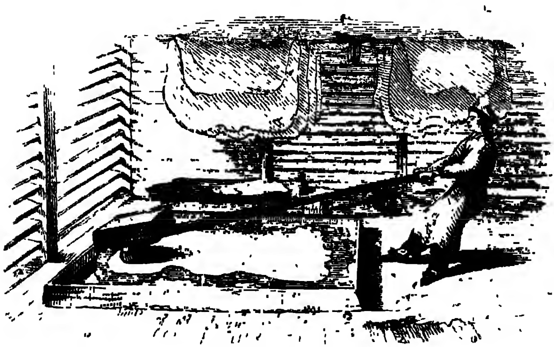
* See Frontispiece.

ooze is a solution of pure gelatine, such as isinglass, which unites with the tannin, and forms a precipitate, more or less dense, according as the ooze is strong or weak. The strength of the ooze is also judged of with tolerable accuracy by its taste, which in strong oozes is highly astringent.

A number of hides being prepared by the processes already described, they are placed one by one, as open as possible, in pits containing nearly spent ooze. *These pits are called handlers,* because the skins are frequently taken out, and *handled* in the early stages of the process. The tannin begins to combine with the gelatine of the skin immediately the two are brought into contact, and hence a weak ooze is spent in a few hours; the skins are therefore removed to a pit containing a stronger ooze, and thus, for the first few weeks, they are shifted daily to oozes gradually increasing in strength. They are removed from the pits by two men, furnished with hooks; and are piled up at the side to allow the spent ooze to drain from them. Each pit contains several dozen hides, and one of the objects of this repeated *handling,* is to ensure the equal action of the tannin upon all the hides. In the course of a few months they are removed to other pits, called *layers,* where the ooze is nearly saturated, and the strength is maintained by a quantity of ground bark (sometimes of valonia) between every two hides. They remain in the layers undisturbed during some weeks.

The time required for tanning hides varies from nine to fifteen months; and for skins from three to five months. In the course of tanning, the whole of the skin or dermis disappears by successive formations of the compound of gelatine and tannin, on both sides of the hide, until all traces of the animal substance disappear. In an early stage a thick whitish line is seen on cutting across a hide: this is a portion of the skin itself; but as the process proceeds this also disappears, and the tanner knows that

the process is complete. The skins are then hung up in lofts to dry, and, once or twice during the drying, they are placed upon a cylindrical bench, and *struck* or smoothed with a square bar, the surface being occasionally wetted: the effect of this operation is to produce on the surface a yellow deposit called *bloom*, or *pitching*. This appearance is so much preferred by shoemakers, that if it were absent they would, probably, refuse to purchase the leather; it is, however, of no advantage, but rather the reverse, being in fact caused by a portion of the interior of the hide dissolved by the saturated ooze, to remove which from the interior to the exterior must prove injurious to the solidity of the leather. When the drying is sufficiently advanced, the hides are submitted to the action of a brass roller, about nine



"FINISHING" HIDES.

inches wide, loaded with from fifteen to thirty cwt. This is called *finishing*, and when complete, the hides are fit for the market.

It will be seen from these details that tanning is a very slow process. Many plans have been adopted for hastening it: such as forcing the ooze into the hide by hydrostatic or atmospheric pressure; but

these have failed, the leather so produced being pronounced to be of inferior quality; parts of the hide which are hard not having time to become perfectly saturated with the tanning liquor, an irregularity in the quality of the leather is the result. The very obvious method of increasing the strength of the ooze more rapidly than is customary, shortens the process, but the leather is hard and liable to crack. The same objection applies to warm oozes. The plan of employing strong oozes, from the commencement, fails, because solutions containing an excess of tannin dissolve the skin. Hence the old method continues to be practised, and to receive the sanction of eminent tanners and of scientific men. Sir Humphry Davy states that leather slowly tanned in weak ooze, appears to be better in quality, being both softer and stronger than when the process is hurried by employing strong ooze from the first.

There is, however, a new process for tanning, which has recently excited considerable attention. It is by Mr. Herepath of Bristol, who has patented the invention. That gentleman is of opinion that the great obstruction to rapid tanning is this:—the skins retain so much of the weakened ooze, that when placed in a stronger ooze, the latter cannot enter the pores already saturated with water or very weak ooze, except after weeks or months of maceration, during which time the exchange is being slowly made. In passing the skins from a weak to a stronger ooze they are therefore pressed between rollers, a pair of which is erected over each pit. The lower roller is about thirty inches in diameter, and is covered with horse-hair cloth; and the upper roller, which is loaded, is only about eighteen inches in diameter, and is covered with woollen cloth. For each pit fifty hides are formed into an endless band, by sewing them together with twine. Upon introducing this band between the rollers, the hides are successively lifted from the bottom of the pit,

strongly pressed by rollers, and then returned into the pit for a fresh supply of ooze. Mr. Herepath states, that each ooze becomes exhausted about two degrees of the barkometer in twenty-four hours, when it is pumped to the next pit of the series. It is said that by this process a strong hide may be completely tanned in six or eight weeks, and calf-skins and *kips* (the hides of young cattle) in from twenty to thirty days. The thickest hides, or *butts*, can by this process be prepared within four months of their being received in the tanner's yard; and the increase in the weight of butt leather, as compared with that made in the usual way, is stated to be as 34lbs. to 28lbs.

The opinions formed of the merits of this process are so contradictory, that the writer cannot venture to quote from them. The efficacy of the method must be tried by the quality of the leather; if it be superior or even equal to that produced by the old process, the new plan must be regarded as a national benefit; but if the leather be hard and brittle, the plan will, sooner or later, be abandoned.

It is generally the object of the tanner to make every hide or skin as heavy as possible, since he sells it by weight. The fair average weight of a good skin of uncurried leather is half the weight of the green hide, and the tanning is not considered successful if the weight be less.

Before taking leave of the tan-yard, the writer must refer to the heaps of spent bark which form a prominent feature therein. This refuse matter is applied to various uses. It is formed into cakes by pressure in iron moulds, and sold in London under the name of *turf*, as a cheap fuel. It also supplies the place of the more expensive article straw, thrown down in the streets of London opposite the house of a sick person, for the purpose of deadening the noise of carts and carriages. A third use is for the purpose of forming hot-beds; when collected in a heap, it slowly putrefies,

and forms a fine vegetable mould. Most of the pine-apples of this country are grown in a compost, into which the spent bark largely enters. After it has served its purpose in the hot-bed, it is transferred to the farmer, who finds it a useful manure.

CURRYING.

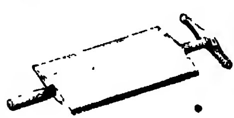
WE will now transfer our skin of leather from the tan-yard to the currier's premises; where, by a series of mechanical operations, it will be transformed into a smooth, shining, and pliable skin, adapted to the purposes of the shoemaker, the coachmaker, the harnessmaker, &c. We will first trace the operations of the currier upon a tanned calf-skin.

The skin is first thoroughly soaked in water, in order to make it pliable; then taken to the beam, and shaved on the rough flesh side, whereby its thickness is considerably reduced, and the unequal surface brought to a tolerably smooth and even one. This is one of the most curious and laborious operations of currying.

The beam shewn in the accompanying figure consists of a strong frame of wood, supporting a stout plank faced with lignum vitæ, and made very smooth; this plank can be set at a greater or less inclination, and sometimes it is permanently fixed in an upright position. The knife, which is double-edged, is a stout rectangular blade, about twelve inches long by five wide; at one end is a straight handle, and at the other a cross handle, in the direction of the plane of the blade. The edge of the knife is brought up by means of a whetstone, and a wire edge is afterwards produced and constantly preserved by means of a small steel tool, which the beam-man always has between his fingers while using the knife. The skin being thrown upon the plank, as in the figure, the

man presses his body against the skin, to prevent it from slipping; and holding the knife by its two handles, and nearly perpendicular to the leather, he

THE BEAM MAN.



shaves off from the thick parts, and, after every shaving, passes a fold between his fingers, and thus ascertains the state of the skin with respect to thinness. When sufficiently reduced by shaving, the skin is again thrown into cold water, scoured, and extended. For this purpose it is placed upon a large stone table, to which the flesh side of the wet skin adheres, and is worked with a tool called the stretching-iron; this is a flat rectangular piece of iron, copper, or smooth hard stone, fixed in a handle, with the corners rounded off to prevent injury to the leather; the workman holds this tool with both hands, and, using plenty of water, scrapes the surface with a very strong pressure, especially at those parts

where lumps and inequalities appear. By the continued action of this tool the leather is extended or stretched, while at the same time the *bloom* is brought to the surface.

When the skin is thoroughly cleansed, and while yet in its wet and distended state, the process of *stuffing*, or *dubbing* (probably a corruption of *daubing)*, is performed. Both sides of the skin, but chiefly the flesh side, are smeared or daubed with a mixture of cod-oil and tallow, which is then well rubbed in by means of a brush, or a piece of old sheep-skin with the wool on. The skin is then hung up in a loft to dry; but as the water only evaporates, the greasy substances sink deep into the pores of the leather. In very moist weather the skins are stove-dried, the fuel for the stove consisting of leather shavings, and thus a most nauseous odour is diffused over the neighbourhood of the currier.

When the skin is sufficiently dry, it is *boarded*, that is, worked with an instrument called the *pommel*. The object of this is to bring up the *grain*, that is, to give the leather a *granular* appearance, and also to make it supple. The pommel is a piece of very hard wood, furnished with a strap on the upper side, for the insertion of the hand,* and grooved (like a crimping board), on the under side, which is convex. The leather is folded with the grain side in contact, and rubbed strongly on the flesh side with the pommel; this part of the process is called *graining*. It is then extended and rubbed on the grain side; this is called *bruising*. The skin is next taken to the beam and *whitened*, that is, the knife is passed lightly over it, whereby the flesh side is thoroughly cleaned and brought to a fit state for *waxing*,—a process which is never performed until the skin is required for immediate sale; for, at this part of our history, the currier stores his skins, because they are

* Hence the origin of the word pommel, from the French *paumelle*, because it clothes the *palm* of the hand.

brought to that state (technically called "finished russet") in which they can be best preserved for any length of time. Previous to waxing, the skin is boarded a second time. The first part of the process of waxing consists in laying on the "colour," or blacking, which is composed of oil, lamp-black, and tallow; the colour is rubbed in thoroughly on the flesh side, by means of a hard brush: it is then *black-sized;* that is, a coat of stiff size and tallow is laid on with a soft brush or a sponge, and well rubbed with a smooth lump of glass called a "slicker;" and lastly it receives its final gloss from a little thin size laid on with a sponge. The skin of leather now curried is called "black on the flesh," or "waxed," in contradistinction to leather which is curried on the hair or grain side, called "black on the grain;" and which is chiefly used for the upper leathers of ladies' shoes; the former, or "waxed" leather, being employed for the upper leathers of men's boots and shoes.

The processes for currying leather on the grain side are similar to those already described, until we come to the process of scouring. *Copperas water,* that is, sulphate of iron dissolved in clean water, or in the water from the tank in which the skins have been soaked, is applied to the grain side of the skin while wet. The iron unites with the gallic acid of the tan, and thus produces an ink dye; the skin is then rubbed over with a brush dipped in stale urine, and when this is dry the stuffing is applied; it is rubbed over with copperas water on the grain side until it is perfectly black. The grain is then raised, and when quite dry, the skin is whitened, bruised again, and grained in two or three ways; a mixture of oil and tallow is then applied to the grain side, and the currying process is complete.

PREPARATION OF THIN LEATHER.

In addition to the tan-yard, properly so called, where the thickest and largest skins of leather are made, there are other establishments which contribute extensively to the immense demand for thin leathers; such as *white* and *dyed* leather for gloves, *morocco* of various colours and qualities for coach-lining, book-binding, pocket-books, &c., being an imitation of that prepared in Morocco, and other parts of North Africa; *roan* for slippers, &c.; a thin leather called *skiver*, used for hat-linings, and an infinite number of other purposes; and, lastly, *shamoy*, or *wash*-leather.

Of all these varieties, white leather alone is not tanned, but tawed. The difference between the two processes is, that the gelatine of the skin is combined with tannin in the one case; and in the other, with something which it imbibes from alum and salt, probably alumine. But, for either process, certain preparations are necessary, whereby hair, wool, grease, &c., are removed, and the skin, thoroughly cleansed, is reduced to the state of simple membrane, called *pelt*.

The preparatory steps vary, according as the skin is covered with wool, or short hair; the one being a valuable commodity, and the other comparatively worthless, its chief use being by the bricklayer to mix with mortar. The hair of kid and goat skins, &c., is therefore detached by immersing the skins in lime, as already described; but as this plan would injure the wool, a different method is adopted. The wool is usually detached from *sheep*-skins before they arrive at the tawers. This is done by the great dealers in sheep-skins, who are called *fell-mongers*; they receive the skins from certain factors, or salesmen, in the skin-market, by whom they are procured from the butchers. The lamb-skins of Italy are imported in casks with the wool on, so that the tawer adopts a-

process for removing it similar to that employed by the fell-monger. They are first cleansed in water, and then scraped on the flesh side. They are then hung up in considerable numbers, in a close, dark, warm room, where they are *sweated*,—that is, putrefactive fermentation soon commences, a thick filthy slime appears on the surface, and the effect of this is so to loosen the wool, that it can be pulled off easily. Much care and judgment are required in regulating the fermentation of the skins, so that their texture be not destroyed. When the wool is removed, the fatty matters are got rid of by the powerful force of a hydraulic press; a large number of skins being piled up, a considerable quantity of fat is expressed; this is afterwards sold to the tallow-chandler. The skins are then worked at the beam; projecting flaps and rough edges are pared off for the glue-maker, and putrefaction is arrested by immersion in lime, for a space varying from two to six weeks. They are first put into a nearly exhausted lime-pit, and afterwards into a stronger one, and are frequently worked about with poles. When taken out they are well worked at the beam, the object being to get rid of a portion of the lime; and this is more completely effected by immersion in a fermenting mixture of dogs' or pigeons' dung, if the skins are to be tanned, and of bran and water if they are to be tawed, the acid of which unites with the lime, and further purifies and softens the skins. During the time that the skins remain in this mixture, they are occasionally taken out and worked at the beam, and are lastly washed in pure water. By such means the pelt becomes a thin extensible white membrane, and is fit for *tanning*, *tawing*, *dying*, *oil-dressing*, or *shamoying*. A brief notice of each of these operations will serve to convey some idea of the extent and importance of the manufacture of thin leathers.

TANNING WITH SUMACH.

The substance used in tanning goat, and other thin skins, is sumach, or the leaves, leaf-stalks, and young branches of the *Rhus coriaria*, and *Rhus cotinus*, shrubs which grow in Hungary, the Bannat, and the Illyrian provinces. They contain much tannin, and a small quantity of a delicate yellow colouring matter. It is said that all the leather made in Turkey is tanned with the bark of the *Rhus coriaria*.

When goat-skins are tanned with sumach, and then dyed on the grain side, they form what is called *morocco* leather; but an inferior morocco is prepared from sheep-skin. When the skins are in the state of perfectly clean white pelt, each skin is sewn by its edges, into the form of a bag, the grain side out; it is then distended with air, and a mordant of tin, or alum, is applied. The object of forming the skins into bags is two-fold, first, to economize the dye stuffs, (some of which are costly,) by dying the skins on one side only; and, secondly, to ensure a perfectly equable action of the dye, and also of the solution of sumach. If the colour is to be red, the skins are immersed in a warm cochineal bath; indigo is used for blue; orchil for purple, &c.; and they are worked by hand until uniformly dyed. For other colours the pelt is tanned before dying. The sumaching is conducted in a large tub, containing a weak and warm solution of sumach. A stronger solution is made in another vessel, and a portion of this, together with some sumach leaves, is poured into the bag, by means of a funnel, through an opening left for the purpose. This is diluted with a quantity of the nearly spent solution in the vat; each skin, after having received its share of the tanning liquid, is handed to a man, who blows into it, and fully distends it; he then ties up the opening, and throws the skin into the vat. About fifty skins are treated in this manner; they all float in the sumach-tub, and

THE SUMACH-TUB.

are moved about by manual labour, or by machinery, during three hours. They are then taken out, and piled on a sloping shelf by the side of the vat, the mutual pressure thus produced causing the sumach to escape slowly through the pores of the pelt. The bags are being constantly shifted by a man, who watches whether the solution escapes from the seams: if so, he secures them by a few stitches. They are next transferred to a second vat, containing a stronger solution than the first; and here they remain about nine hours, at the end of which time the tanning is complete. The skins are ripped open, rinsed, and drained. The colour of the fine red skins is finished in a weak bath of saffron; and, lastly, all the skins, of whatever colour, are stretched upon a smooth sloping board, and *struck*,—that is, scraped and rubbed out, until they become smooth and flat. Sometimes they are sponged on the grain side with linseed oil, in order to promote their glossiness in the subsequent process of currying.

The skins are then removed to a loft, and dried.

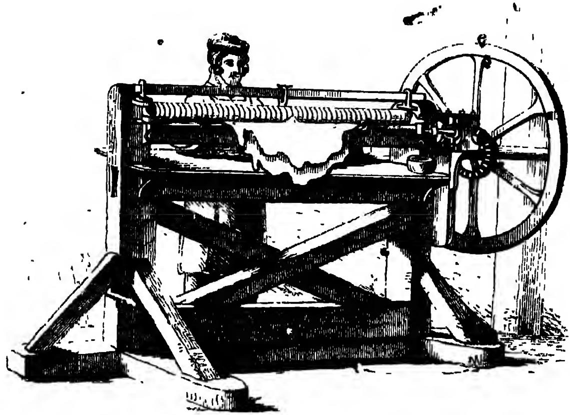
In drying they assume a horny texture, and are said to be *in the crust*. After this comes the process of currying, or finishing. The skins are again placed upon the smooth sloping board, and rubbed several times with the pommel, and also with a glass ball, cut with smooth sides upon its surface; this polishes them, and makes them firm and compact.

"FINISHING" THIN LEATHERS

The grained, or ribbed appearance, peculiar to morocco leather, is imparted by a ball of box-wood, round the circumference of which are cut a number of narrow ridges. This is passed many times over the skin with a firm pressure, and its effect is not only to improve the surface of the skin, but also to add to its pliability and softness.

The preparation of an imitation morocco from sheep-skins, does not differ essentially from the processes just described; but there is one remarkable process applied to sheep-skins, which must be noticed. When they are in the state of pelt, they are *split*; that is, every skin is divided into two skins of the same size, but, of course, of only half the thickness of the pelt. This is effected by means of a very beautiful machine called the "skin-splitting machine." It consists of two rollers, the lower one of solid gun-

metal, and the upper one composed of rings of the same material; these cylinders are made to move slowly in opposite directions; and between them, but not in contact, is a knife, with a sharp cutting



SKIN-SPLITTING MACHINE

edge, to which a rapid reciprocating motion is imparted. In order to *split* a skin, a man stands on the side of the machine, opposite to the knife edge, and, upon the lower or solid roller, spreads evenly the end of a skin or pelt; it is caught up by the rollers, and dragged forward against the edge of the knife, by which it is divided; one half going above, and the other below the plane of the blade. During the whole of the operation the man continues to adjust the skin upon the lower roller, the smooth solid surface of which gives support and stability to the skin, while the upper roller, being composed of moveable rings, adjusts itself to any unevenness of the membrane. In parts where it is thin, the rings are depressed; where it is thick, they are elevated; hence no part escapes the action of the knife, and no

holes are produced in either half. The men are furnished with gloves, to prevent their fingers being caught up by the rollers. About two minutes are occupied in splitting a sheep-skin, during which time the knife is moved to and fro nearly three thousand times. When three or four of these machines are at work in one room, the noise is deafening.

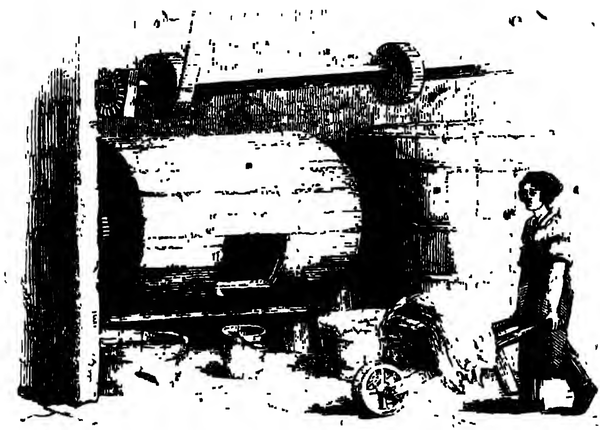
In order to show the precision with which this beautiful machine works, sheep-skins have been split into *three* parts of equal size; the grain side being used for skiver, &c.; the middle for making parchment; while the flesh side was transferred to the glue-maker. The divided skins, or skivers, are sumached in a short time, their thinness rendering the sewing up into bags unnecessary.

TAWING.

THE preservation of an animal skin, by means of alum and salt, is called *tawing;* and the object is to employ such materials as will not interfere with the production of a pure white leather. In all the finer kinds of leather-dressing, the perfect purity of the pelt is of the utmost importance, for without it the subsequent operations would be thrown away; every particle of dirt, or lime, which is allowed to remain, appearing as a speck or a flaw. The purity of the water used for rinsing the skins, is also a point of great importance. At Messrs. Bevington's manufactory (which the writer was permitted to inspect) a sufficient supply of distilled water is obtained from the boiler to the steam-engine, which is made larger than usual for this express purpose.

Kid-skins, for the best kid-leather, and sheep, or lamb-skins, for an inferior sort, being reduced to the state of pelt, the first process in tawing, is to "give them a feeding" with alum and salt. About three pounds of alum, and four of salt, are used to one hundred and twenty middle-sized skins. The solu-

tion, together with the skins, is put into a drum, or tumbler, to which a rapid motion is imparted. The



action of the alum and salt upon the skins is not well-known, but it is supposed that alumine and gelatine form some definite compound, and that the salt serves to whiten the skins. After some time they are taken out, washed in water, and then put into bran and water, where they are allowed to ferment, till the superfluous alum and salt are removed, and the thickness produced by them is reduced. They are next transferred to the drying loft, stretched on hooks, and allowed to remain till fully dry. They now form a white, tough, brittle leather; but the glossy finish and softness of kid is imparted by a dressing, composed of twenty pounds of the finest wheat flour, and the yolks of eight dozen eggs.* This paste,

* This egg-dressing is indispensable in the preparation of white lamb and kid-leather. The eggs used for the purpose are imported from France and Flanders; and at the time of the writer's visit to Messrs. Bevington's factory, they had a stock of 60,000 eggs pickled in salt, which preserves them admirably.

diluted with water, is put into a drum, and the skins are made to rotate therein, when they so completely imbibe the egg-liquor, that scarcely anything more than water remains. This dressing is generally repeated before the skins are hung up to dry. But the softness and elasticity yet remain to be given. The skins are dipped into pure water, and allowed to remain for a few minutes; they are then spread out, and worked upon a board, and *staked* upon the *stretching* or *softening* iron. This is an iron plate,

"STAKING" TAWED LEATHER.

rounded over at the edge, mounted upon an upright beam, and fixed to a heavy plank, well secured in the floor. By these processes the skins are considerably extended in length, and all hard points and roughnesses removed. They are finally smoothed with a hot iron, and are then ready for the glover.

DRESSING IN OIL,

Consists in first soaking the skin in water, and then, by continued hard rubbing, forcing oil or grease into its pores. As the water evaporates, the oily matter combines in some way with the fibres of the skin; renders it permanently soft, and by keeping out the water prevents it from decay.

A process of this kind was formerly applied to the skin of the Chamois goat, and hence arose the term *chamois, shammy*, or *shamoyed*, as applied to the leather itself, and *shamoying* to the process. As this is the only kind of leather which, when dyed, will bear washing without the colour being materially injured, it is also called *wash*-leather.

Wash-leather is prepared, in this country, from doe's or sheep's-skin: and for the inferior kinds, the flesh side of sheep's-skin, as obtained from the split hide, is employed; the other half, or grain side, being tawed for skiver-leather. Indeed, it is common always to get rid of the *grain* before a skin is shamoyed; because, by doing so, the extensibility and softness of the skin are much increased. The grain is removed by an operation called *frizing*; that is, one end of the skin is wrapped over a pole, the grain side uppermost, and then the whole surface is scraped with a round knife, or with pumice-stone.

The grain being removed, the skins are placed in some bran liquor, and then wrung out; they are afterwards spread upon a table, sprinkled slightly with oil, and folded up in balls of four each, and beaten by a number of heavy wooden hammers in the *fulling stocks*. The heads of the hammers are covered with copper, and they work in a kind of trough, in which the skins are placed. After having been beaten for two or three hours, according to their texture and the state of the weather, they are taken out, exposed to the air, oiled and fulled several times,

until all appearance of greasiness has disappeared. They are next hung up in a warm room, when a kind of fermentation takes place, which opens the pores of the skin and promotes the combination of the oil. They are then scraped with a blunt concave knife, and scoured in a weak warm potash lye, in order to get rid of the uncombined oil. Having been washed in water, they are gently dried, smoothed, and made supple by the stretcher iron, or by passing them between rollers.

STATISTICS OF LEATHER.

In the year 1830, the duty on leather was wholly repealed; so that there are now no means of ascertaining the quantity produced in any one year. The yearly production, on an average of three years, ending in 1822, was 48,244,026 pounds. In this year the duty was diminished from 3*d.* to 1½*d.* per pound; and the average production of the next three years showed an increase of 30 per cent. The repeal of the duty and the increase in population have, doubtless, increased the consumption of leather to an equal, if not greater, extent. It has been calculated that the annual production, at this time, is about 82,000,000 pounds; the value of which, taking one quality with another, at 1*s.* 4*d.* per pound, amounts to 5,466,000*l.* It is supposed that the value of the leather forms only one-third of the finished articles, so that the ultimate value of the manufacture, in Great Britain alone, must be 16,400,000*l.* Some estimates are even higher than this, and make the aggregate value of leather goods to exceed 21,000,000*l.* per annum. "Nor will this amount appear excessive," says Mr. M'Culloch, "if we consider that there is only a very small proportion of the people, however poor they may be, who do not wear leather shoes or boots; that the use of leather gloves is general among all but the labouring classes; and that the harness of

horses used for pleasure, as well as those used for agricultural and other business operations, is made with this material, besides an endless variety of things in daily use, which will suggest themselves to every one's mind."

Some idea of the importance of the leather manufacture may be formed by considering the value of the shoes annually manufactured. It is generally supposed that the expenditure upon shoes may be taken, at an average of the whole population, at 10*s.* per annum for each individual, young and old, which, supposing the population to amount to nineteen millions, would give 9,500,000*l.* for the value of shoes only; but taking the value of shoes at only 8*s.* 6*d.* each individual, it gives 8,075,000*l.* for the amount. It has been supposed that the value of saddlery, harness, gloves, &c., is, at least, equal to that of shoes; but this estimate is thought to be too high.

The leather manufacture does not seem to exert any injurious action on the health of those engaged in it. Tanners are exposed to disagreeable odours, arising from putrefying skins combined with the smell of lime, or of putrid substances used in dressing them. The smell of the tan-pits is penetrating, but not by any means unwholesome; the men do not seem to suffer from any of these causes; and, although constantly exposed to wet and cold, they are robust, and disease is almost unknown among them.

In consequence of the odours diffused by tan-yards, they are generally situated at the outskirts of a town. During a long period, Bermondsey was the principal seat of the leather manufacture in England, on account of the Thames tide-streams affording an abundant supply of water. Although the Bermondsey manufactures are more extensive than ever, tan-yards are established near most of the towns of this country.

Curriers and leather-dressers sometimes suffer from the bent posture required by their work: this affects the head; but otherwise they are exposed to no injurious agent.

THE

MANUFACTURE OF PARCHMENT.

THE preparation of parchment from the skins of animals is closely connected with the manufacture of leather, and therefore requires to be noticed in this place.

Parchment derives its name from *Pergamus*, an ancient city of Mysia, where it is said to have been invented by Eumenes II., king of that place, (who reigned B.C. 197—159,) in consequence of the prohibition, by Ptolemy Epiphanes, to export papyrus from Egypt. It is, however, nearly certain that the invention must be referred to an earlier date, and that Eumenes was only an improver, or the patron of some improvements, in the manufacture at Pergamus.

As soon as men had invented written characters, they would naturally seek after the means of preserving some record of their most important transactions. Memorials of stone and of metal were long used for solemn occasions, while tables of wood were in more familiar use; leaves of trees and the inner bark were convenient substitutes for leather; but, perhaps, the most useful material was animal skin or membrane, which seems to have been used at a very remote period,

Some kind of animal membrane, or parchment, seems to be indicated in the "great roll" which the Lord commanded the prophet Isaiah to write "with a man's pen," (Isa. viii. 1,) and also the "roll of a book" in which Jeremiah wrote the words of the Lord, and which was cut with a pen-knife and cast into the fire, piece by piece, by Jehoiakim, king of Judah, as it was read in his presence, (Jer. xxxvi. 2,

22, 23), and a book described by Ezekiel as being written within and without with "mourning, lamentations, and woe." (Ezek. ii. 9.)

The ancient Persians are said to have written their records upon skins, and it is known that the Ionians employed the skins of sheep and goats for writing on, at a very remote period, understood to be many centuries before the time of Eumenes. The antiquity of parchment as a material on which the Holy Scriptures were transcribed, is shown also by an interesting discovery of the late Dr. Buchanan, who found in the record-chest of the Black Jews at Malabar, an Indian copy of the Pentateuch, written on a roll of goats' skins, dyed red. This ancient and beautiful manuscript was discovered in 1806, and is now deposited in the public library at Cambridge. The roll measures forty-eight feet in length by twenty-two inches in breadth. The book of Leviticus, and the greater part of the book of Deuteronomy are wanting; and it appears, from calculation, that the original roll measured not less than ninety feet. In its present condition it consists of thirty-seven skins, with one hundred and seventeen columns of perfectly clear and legible writing.

Although the word *roll* occurs several times in the Holy Scriptures, the word *parchment* is not mentioned more than once. (See 2 Tim. iv. 13.) The word in the original Greek, however, is *membrane*; and it is stated that the name *Pergamena* was not used until several centuries after the death of Eumenes.

We are not clearly informed of the ancient method of preparing parchment. In the seventh century it seems nearly to have superseded the use of papyrus, and also to have been used for strengthening and supporting written leaves of that fragile material. About the eleventh century the manufacture degenerated, from the circumstance, it is supposed, of writers preparing their own parchment. This practice is recommended by Hildebert, archbishop of Tours,

(born in 1054,) who, in a sermon on the "Book of Life," which he recommends his hearers to obtain, says—"Do you know what a writer does? He first cleanses his parchment from the grease, and takes off the principal part of the dirt; then he entirely rubs off the hair and fibres with pumice-stone: if he did not do so, the letters written upon it would not be good, nor would they last long. He then rules lines that the writing may be straight. All these things you ought to do, if you wish to possess the book which I have been displaying to you." About this period parchment was a very costly material, and hence arose the practice of paring or washing off the contents of an older manuscript for the sake of the material. Thus, many a beautiful poem or valuable history has been sacrificed to make way for a monkish legend; but ingenious and learned men having discovered means for deciphering the original writing, many valuable old classic productions have thus been preserved to the world. An old French writer, speaking on this subject, says:—"Some parchment has been restored three or four times, and has successively received the verses of Virgil, the controversies of the Arians, the decrees against the books of Aristotle, and, finally, the books of Aristotle themselves. Parchment is like an easy man, who is always of the same opinion as the last speaker." The practice of using parchment many times over was so common in the fourteenth and fifteenth centuries, that the diploma of the Imperial Notary of Germany expressly prohibited the use of *scraped* vellum in drawing deeds.

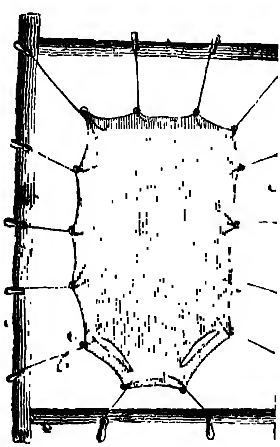
The invention of paper, in great measure, superseded the more costly vellum or parchment, although this substance was frequently used in printing. Dr. Dibdin states that almost all the known works before 1462 are printed upon vellum; the Psalters of 1457 and 1459 are upon vellum; and that of the Bible of 1462. More copies have been described upon vellum than upon paper.

PREPARATION OF THE SKINS.

DR. DIBDIN, in his *Bibliographical Decameron*, quotes a little book of Arts and Trades, which appeared at Frankfort in 1568, 12mo, with cuts, in which the parchment-maker is seen at work with tools and apparatus closely resembling those now in use; so that the processes about to be described have, probably, been followed during many centuries.

The skin of almost every animal is capable of being made into parchment; but that of the sheep or the she-goat is usually preferred. The finer kind of parchment, called *vellum*, is made from the skins of calves, kids, and dead-born lambs; the stout parchment, used for drum-heads, is made from the skins of asses, calves, or wolves, preference being given to the latter; the parchment of battledores is from asses' skin; and for sieves, the skin of the he-goat is preferred.

These skins are all prepared in the same way, or nearly so. Wool, hair, and fatty matters are got rid of by some of the processes which have been already described, and, when thoroughly cleansed, the skins are stretched in such a way as to prevent puckering, and to admit of their being easily worked. For this purpose a stout wooden frame, called a *herse*, is employed. It consists of four bars, perforated with a number of holes, in each of which is a wooden peg, which works in the same manner as the peg of a violin or a guitar. In order properly to stretch the skin, a number of pieces of twine are tied firmly to its edges, and,

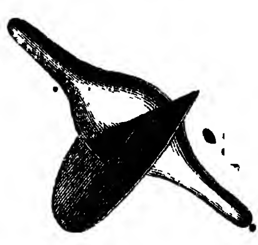


THE HERSE

to prevent them from slipping when the skin is strained tightly, each string is tied round a small wad or ball, formed by rolling up a shred of skin, and wrapping this into a small fold at the side of the skin which is to be strained. Sometimes skewers of several sizes are used; these are stuck into the edges of the skin, and the string is then firmly secured to them. The other extremity of each string is next passed through a hole in the side of the peg, and in turning this the string is wound round it, and thus the skin is gradually and equally strained. The pegs are first turned by hand, and afterwards with a key. The greatest possible care is required to prevent the formation of wrinkles.

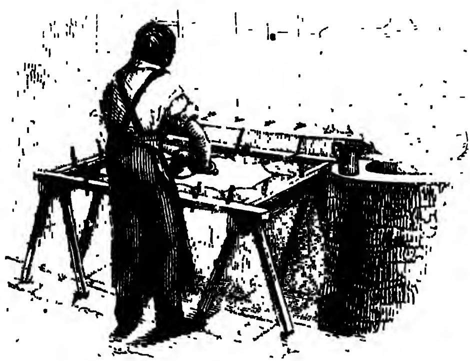
SCRAPING.

The skin being properly strained, the herse is set up against the wall, and the skinner proceeds to scrape the surface with a semicircular double-edged knife, attached to a double wooden handle. Thi is sometimes called a *half-moon knife*. The skinner uses this knife with both hands, and pressing the edge against the skin, shaves off all fleshy substances. He next turns the herse so as to expose the grain side of the skin, and passes the knife over every portion of it. By this means dirt, slime, and a considerable quantity of water, are removed.



HALF-MOON KNIFE.

The next process is *grinding*. The skin is placed upon trestles, and sprinkled on the flesh side with finely powdered chalk or slaked lime, and then rubbed in all directions with a flat surface of pumice-stone. The grain side of the skin is next ground, but without the addition of chalk or lime. The knife is again passed over the skin, and the scouring with chalk and pumice-stone is repeated. This scraping with the knife is called *draining*, and serves to whiten the skin. The skinner then rubs fine chalk over both



sides of the skin with a piece of lamb-skin that has the wool on: this makes the skin smoother, and gives it a white down or nap, but great care must be taken not to scratch the surface. The skin is then removed to a covered shed to dry. In warm weather a moist cloth is occasionally applied to it, and the pegs are tightened. When perfectly dry, it is well rubbed with the woolly side of a lamb-skin, in order to get rid of the chalk. If any greasy matter should now be detected in the parchment, the skin is removed from the herse, and again steeped in the lime-pit for several days; but if the result is satisfactory, the

skin is removed from the frame by cutting it all round.

The skin is then passed to the *parchment-maker*, who stretches it upon a machine called the *summer*, which is nothing more than a calf-skin mounted upon a frame. The tail of the skin being placed downwards, the parchment-maker then takes a sharp circular knife, and passes it over the outer surface, in an oblique downward direction, paring off about half of its thickness, and leaving it perfectly smooth; this is an operation requiring great flexibility of the wrist and considerable skill. The skin is scraped on the grain side only, and any remaining roughness is removed by rubbing with pumice-stone upon a kind of form or bench, covered with parchment, and stuffed with flock; this process leaves the parchment fit for writing on. If any small holes appear in the skin, they are stopped by cutting the edges thin, and pasting on small pieces of parchment with gum water.

Parchment is coloured green for binding. The following is a common method of imparting the colour:—In 500 parts of distilled water are boiled eight of cream of tartar, and thirty of crystallized verdigris; when the solution is cold, four parts of nitric acid are added. The parchment is first moistened with a brush, and the colour then spread evenly over the surface. Polish is given by white of egg or mucilage of gum arabic.

GLUE BOILING.

THE

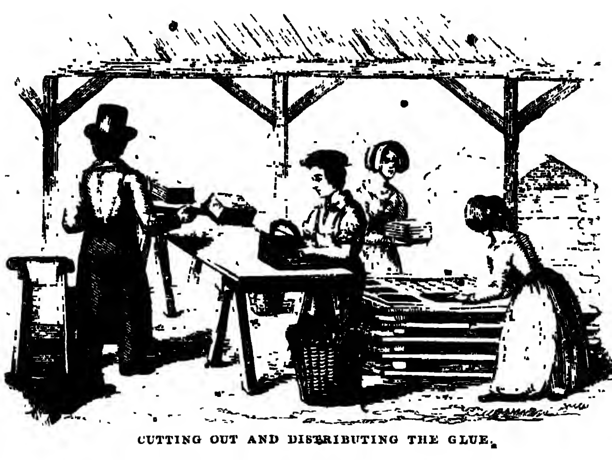
MANUFACTURE OF GLUE.

GLUE is a preparation of gelatine in a dry state, and is made from the refuse of the leather-dresser and the parchment-maker. All the projecting flaps, the roundings, scrapings, and cuttings of skins, anything, in short, that contains gelatine, may be employed in the manufacture of glue. The following account of the process is chiefly derived from a visit to the works of Mr. Alfred Bevington, of Bermondsey, who has kindly permitted sketches of his machinery to be taken.

On receiving the refuse material from the leather-dresser, the first process is to make it clean and to get rid of matters which do not afford glue; the pieces are, therefore, immersed in a lime-pit, and when sufficiently steeped they are placed in baskets, and rinsed in a stream of water, and then placed on hurdles to dry. Whatever lime remains is converted into chalk by exposure to the air; and although lime would be injurious to the after processes, yet the presence of a minute portion of chalk is immaterial.

The gelatine is extracted from the pieces by boiling. For this purpose they are placed in a rope cloth, which is spread open within a large iron cauldron; a light framing of iron is contained within the cauldron to prevent the cloth from sticking to its sides. Water is then added, which is gradually brought to the boiling point; as the animal substances sink, fresh quantities are added, the whole being

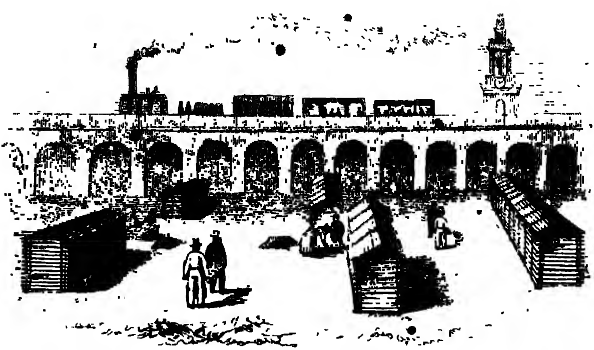
occasionally stirred up and pressed down with poles. As the boiling proceeds, portions of the gelatine are taken out and set aside to cool, and when, on cooling, a clear mass of jelly is produced, the boiling is judged to be complete. The ends of the bag are brought together by means of cords, and by giving motion to the machinery over the cauldron the bag is slowly lifted out of it; the gelatine drains off, and this is further assisted by causing a portion of the bag to coil round the beam as shewn in the frontispiece. The solution of gelatine in the cauldron can, if necessary, be further evaporated by continuing to apply heat. The contents of the bag are boiled a second and a third time for making size, and when the solutions are too weak to produce either glue or size, they can be economically used instead of water. When nothing more can be extracted the refuse is sold to the manure-dealer.



CUTTING OUT AND DISTRIBUTING THE GLUE.

When the glue is thick enough it is drawn off into a vessel called a *settling-back*, and maintained at the temperature necessary to keep it liquid.

Here the solution deposits its solid impurities, and is further clarified by the addition of substances which vary according to the skill or judgment of the manufacturer. The glue is next run off into wooden coolers, which are about six feet long, one foot broad, and two feet deep, where, as it cools, it gradually hardens into a tolerably firm jelly. It is then cut out by a spade into square cakes, each of which is placed in a sort of wooden box, open in several slits or divisions to the back; the glue is cut into slices by passing a brass wire, attached to a kind of bow, along the slits. The slices thus formed are placed upon nets stretched in wooden frames, and removed to the glue-maker's field.



GLUE-MAKER'S FIELD AT BERMONDSEY.

The frames, as they are filled, are placed in piles with an interval between every two frames, so that the air may have free access to them. Each pile is covered with a roof to protect it from the weather. The glue is turned two or three times a day, for which purpose the roof is removed, and the uppermost frame placed on the ground. The cakes being turned one by one, a second frame is placed upon

the first, and the cakes on it turned in like manner, this goes on until a new pile is formed near the spot where the old one stood.

The drying of the glue is the most anxious and uncertain part of the manufacture. A material change in the weather may greatly injure it. If the air becomes very warm, the cakes may become so soft as to lose all shape, or they may even unite with the strings, so as not to be removed without dipping the net in boiling water; or they may even melt entirely, and flow out of the frames. On the other hand, a sudden frost may freeze the water in the glue and cause it to crack in all directions, rendering re-melting necessary. A thunder-storm sometimes prevents a whole field of glue from hardening; a fog will sometimes cause a general mouldiness; a wind too hot or too dry, by making it dry too rapidly, may render it unsightly and unfit for the market. Hence, it is important to select the most temperate season of the year for the manufacture.

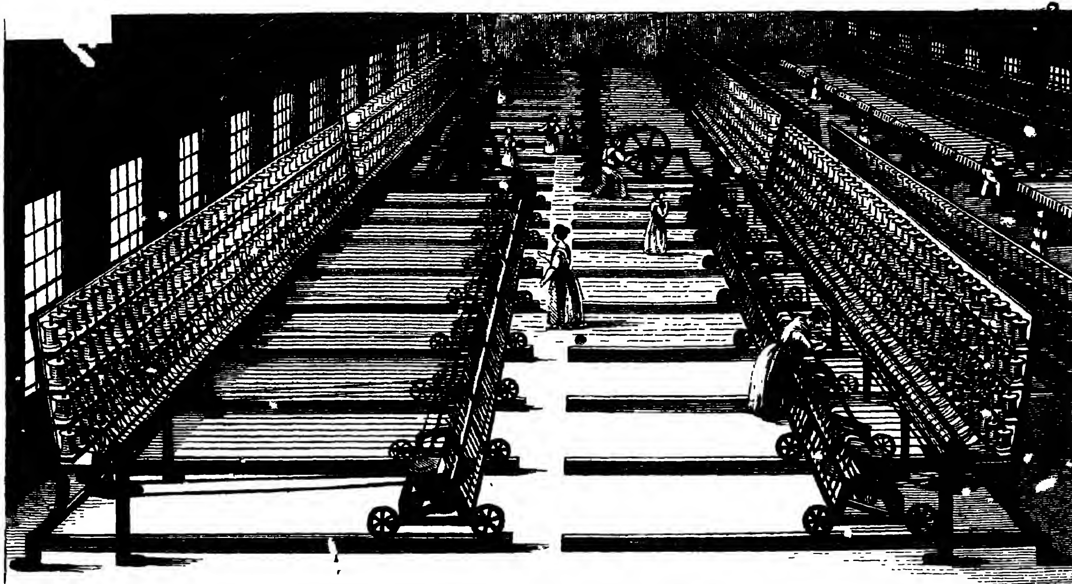
When the glue is about three parts dry it is removed from the open air into lofts, where in the course of some weeks or months the solidifying is completed. During this time the surfaces become mouldy and otherwise soiled, they are therefore scoured with a scrubbing-brush in hot water, and set up to drain; and lastly, dried in the stove-room at an elevated temperature, which, when they are once solid, only serves to harden and improve them.

SCOURING.

Glue is usually judged of by its strong dark colour and freedom from cloudy and black spots when held before the light. The best glue swells considerably,

but without melting, on immersion in cold water, and renews its former size and properties by drying. In melting glue for use, it should be broken into small pieces, soaked for twenty-four hours in cold water, and then melted, very slowly, over a fire, keeping it frequently stirred; when prepared in this way, it becomes, when cold, a firm jelly, which requires only a little warming to fit it for use. If spread over wood with a stiff brush, pieces thus joined, will, in two or three days, be so perfectly connected, that they will as readily break in any other part as at the junction. Glue must not be used in a freezing temperature.

Other kinds of glue are prepared for particular purposes. Fish-glue, also called *isinglass* and *ichthyocolla*, is prepared from the skins and mucilaginous parts of fish. A strong compound glue is made by infusing during twenty-four hours common glue in small pieces with isinglass in a sufficient quantity of spirits of wine to cover the mixture. Heat is then cautiously applied, and, when melted, a quantity of powdered chalk is added, until the whole is of an opaque white. A strong glue, which will resist water, may also be made by adding half a pound of common isinglass to two quarts of skimmed milk, and evaporating the mixture to a proper consistence.



MULE SPINNING

THE USEFUL ARTS AND MANUFACTURES OF GREAT BRITAIN

THE MANUFACTURE OF COTTON YARN.

PART II.

THE locality of a manufacture is usually determined by the facility with which water-power, fuel, and iron can be obtained; for, where they are abundant, machinery can be made and put in motion at small cost: and, in this respect, many parts of Lancashire and its neighbourhood are highly favoured. There is perhaps no spot of ground in the world more advantageously situated for manufactures than the tract lying between the Ribble and the Mersey. The neighbouring hills pour down a number of rapid streams, which furnish water-power to many hundred mills, feed navigable canals, supply water for scouring, bleaching, printing, dyeing, and other processes. The river Irwell is said to be "the hardest worked river in the universe;" for, besides washing, bleaching, dyeing, &c., it is calculated to move, with its tributaries, not fewer than three hundred water-wheels, some of which are of very large size. South Lancashire is rich in coal fields, which are worked with great ease and economy; the neighbouring counties furnish abundance of iron; the great sea-port of Liverpool supplies the raw material, and exports the beautiful fabrics produced in this industrious district.*

Here it is that the cotton factories are principally situated,—those stupendous buildings which fill the

* A considerable quantity of manufactured cotton goods is also exported from the ports of London, Hull, Bristol, and Newcastle-upon-Tyne.

mind with astonishment, until their internal arrangements are inspected and understood, and then with admiration and delight. Whether the power be steam or water, the plan of the building is the same. A cotton factory is a huge square structure, often containing seven or eight stories, the rooms of which may be two or three hundred feet in length, lighted by numerous windows, which have a singularly picturesque appearance by night, when seen from without. "The operations carried on within its walls," says Mr. Baines, "are numerous, and every one of them is performed by machinery, without the help of human hands, except merely in transferring the material from one machine to another. It is by iron fingers, teeth and wheels, moving with exhaustless energy and devouring speed, that the cotton is opened, cleaned, spread, carded, drawn, roved, spun, wound, warped, dressed, and woven. The various machines are proportioned to each other, in regard to their capability of work, and they are so placed in the mill as to allow the material to be carried from stage to stage with the least possible loss of time. All are moving at once, the operations chasing each other; and all derive their motion from the mighty engine, which, firmly seated in the lower part of the building, and constantly fed with water and fuel, toils through the day with the strength of perhaps a hundred horses. Men, in the mean while, have merely to attend on this wonderful series of mechanism, to supply it with work, to oil its joints, and to check its slight and unfrequent irregularities; each workman performing, or rather superintending, as much work as could have been done by two or three hundred men sixty years ago. At the approach of darkness, the building is illuminated by jets of flame, whose brilliance mimics the light of day, the produce of an invisible vapour generated on the spot. When it is remembered that all these inventions have been made within the last seventy years, it must be ac-

knowledged that the cotton mill presents the most striking example of the dominion obtained by human science over the powers of nature, of which modern times can boast. That this vast aggregate of important discoveries and inventions should, with scarcely an exception, have proceeded from English genius, must be a reflection highly satisfactory to every Englishman."

SORTING THE COTTON, WILLOWING, BATTING, BLOWING, AND LAPPING.

THE importers of cotton employ certain brokers in Liverpool, who set a value upon the sample, and find purchasers to any amount. The buyers, who are the spinners all over the country, and the Manchester cotton dealers, also employ brokers to make their purchases. The brokers charge, both to seller and buyer, a commission of ten shillings for every hundred pounds worth of cotton.

The cotton is seldom unpacked until it arrives at the mill, the purchases being all managed by samples. When it is unpacked, the first thing to be done is the sorting, and in this much care and skill are required; for the different bags furnish different qualities of cotton, and it is necessary to produce yarn of uniform quality, at the cheapest rate. In order, therefore, to equalize the different qualities, the contents of all the bags are mixed together in the following manner. A space being cleared and marked out on the floor, the cotton contained in the first bag is scattered over this space, so as exactly to cover it; the contents of the second bag are, in like manner, spread over the first, and the cotton in all the other bags is disposed in a similar manner; men and boys tread down the heap, which is called a *bing* or *bunker*, until at length it rises up in shape and dimensions very much like a large hay-stack. Whenever a supply of cotton is

taken from the bing, it is torn down with a rake from top to bottom, by which means it is evident the contents of the different bags are collected together in a mass of uniform quality and colour. In mixing different qualities of cotton, it is usual to bring together such only as have a similar length of staple. A portion of the waste cotton of the mill is also mixed in the bing, for making the lower qualities of yarn. For higher numbers, as well as for warps, a finer quality of cotton must be selected; and thus it will be seen that the formation of the bing is an important operation, the quality of the goods produced depending upon it.

In this state the cotton contains sand, dirt, and other impurities, and the fibres are matted together by the pressure they were subjected to in packing. To open the fibres, and get rid of the sand, &c., the cotton is put into a machine called a *willow*. This consists of a box or case, containing a conical wooden beam, studded over with iron spikes: this beam is made to turn round five or six hundred times in a minute. The cotton, as it is torn down from the bing, is put in at one end of the machine, where it is caught by the spikes, tossed about and shaken with great violence, and gradually driven forward to the other end. The sand and other heavy impurities fall out of the machine, through an open grating at the bottom; the dust and lighter matters pass off through a series of wire openings, and the cleaned cotton is sent down a shoot into the room below.

If the cotton is of fine quality, it is beaten, or *batted*, with hazel or holly twigs. For this purpose, it is spread upon a frame, the upper part of which is made of cords; and is quite elastic. A woman, with a rod about three or four feet long in each hand, beats the cotton with great violence, producing a similar effect to the bow-string of the Hindoo. Any loose impurities which remain fall out between the cords;

seeds, and fragments of seed-pods, which adhere to the cotton somewhat firmly, are picked out by hand. By this method, the tangled locks disappear, the cotton is thoroughly opened, and made quite clean, without injuring the staple.

The coarser qualities are passed at once from the willow to the *scutching* or *blowing* machine, which does the work of batting, only in a more violent manner, and is, therefore, not adapted for fine qualities; but, in coarser spinning, is in general use to prepare the cotton for the carding-engine, as was the case at one of the mills visited by the writer. The cotton, as it was shot down from the willow, was received upon an endless band, called a *creeper*, ingeniously covered with laths of wood moving upon rollers: it supplied cotton to the various blowing-machines placed at equal distances across a long room. Each machine was attended by two lads, one of whom weighed a portion of the cotton, while the other spread it upon an endless band employed to feed the machine. This band was also formed of laths, placed crossways and fastened together, in

preference to cloth, which is apt to sink along the middle, and thus feed the machine irregularly. Two or three of the laths were painted black, for the purpose of dividing the surface of the feeder into two or three equal parts. The feeder being constantly urged, with a slow motion, towards the mouth of the machine, it was the duty of the attendant, as soon as a black lath appeared, to begin to spread the weighed quantity of cotton, and to make it cover the whole surface until another black lath appeared: he was then ready to spread another weight of cotton. Thus, while one part of the feeder is constantly supplying the insatiable appetite of the machine, another part returns for a fresh supply. As soon as the cotton enters the jaws of the machine, it is seized by two rollers, and immediately exposed to the blows of a *batting-arm,* or beater, which is turned round with great velocity within a kind of drum, of which the arms of the beater form the diameter. The solid impurities fall through a grating, but the dust and lighter matters are sucked up through a shoot, in which the air is rarefied by a revolving fan. The wind produced by the batting-arm drives the light cotton filaments onward, where they are assaulted by another batting-arm: they are again urged forward, and blown with tolerable regularity over the surface of a wire-gauze drum, which is constantly revolving. Beneath this drum, and in close contact with it, is an endless band moving on rollers, which receives the cotton, and conveys it out of the machine. The pressure of the drum upon the band condenses the cotton into a filmy sheet; that is, the fibres cling together sufficiently to allow the cotton to be wound upon an iron rod as it leaves the machine, and in this state it is called a *lap.* The advantage of this is, that a uniform thickness can be presented to the carding-engine, which is a necessary condition.

In spinning fine yarns, this method of preparing the laps does not answer so well as forming them by

hand. This practice was introduced by Arkwright, and it is done in various ways. In Mr. Houldsworth's mill, at the time of the writer's visit, the following method was adopted:—A boy was furnished with two qualities of cotton, contained in separate baskets: from one of these he took a certain quantity, and put it, together with a weight which hung from the beam of the scale, into the pan until the scale went down; the weight was then taken out, and its equivalent

FORMING LAPS BY HAND.

made up from the second basket.* The cotton thus weighed was taken to a canvass strip, one half of which was extended along a kind of frame near the wall, while the other half rested on the floor. The

* By this method cotton of various degrees of fineness may be mixed in any proportion. Suppose, for example, the manufacturer wishes to produce yarn from two qualities of cotton in the proportion of 3 of one to 2 of the other. The large scale weight will be $1\frac{1}{4}$ or $\frac{5}{4}$. He first puts a small weight equal to $\frac{1}{2}$ into the scale pan, with the first lot of cotton, and thus gets $\frac{3}{4}$ of the quantity required; then taking out the weight he adds cotton from the second basket, to the value of $\frac{2}{4}$ or $\frac{1}{2}$.

lad distributed the cotton over this cloth, batting, and slightly raising it with a rod, and then flattening it with a kind of fan formed by the union of five rods. The boy then rolled upon an iron spindle the portion of the cloth covered with cotton, and, in doing so, dragged upon the frame the remaining half, which was in like manner covered with cotton, and rolled up. The laps thus formed were placed in a heap in the lower part of the frame, ready for the carding-engine. In forming these laps the greatest precision is required, because the size of the yarn to be produced depends upon the quantity of cotton spread over a given surface, and any irregularity in the spreading is likely to interfere with the uniform thickness of the yarn. As the cotton varies slightly in weight, according as the weather is wet or dry, it is sometimes usual to weigh it with a cotton weight, formed by packing a quantity of cotton into a hollow copper tube or ball, pierced with holes. As this weight is about as much affected by changes in the weather as the cotton itself, an equality is thus preserved in forming the laps.

FANS USED IN BATTING AND LAPPING.

CARDING.

THE cotton, which is still in a confused and tangled state, has now to be carded, upon the regularity and perfection of which process depends much of the success of spinning, and also of the beauty and durability of the stuff to be woven. It has been already explained, that a cotton card is a sort of brush, containing wires instead of bristles. The cards are made of bands or fillets of leather,* pierced with

* By a recent improvement, the cards are formed of alternate layers of cotton, linen, and Indian-rubber.

numerous holes, in which are fixed bent pieces of iron wire, called dents or teeth. Each piece of wire, by being bent, forms two teeth; thus: \\ These must be of equal size and shape; they must stand at equal distances, and be equally inclined to the curved surface of the drum, round which the cards are to be lapped. The leather must also be of the same thickness throughout, or the teeth will not stand at precisely the same height.

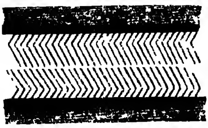
When cards were made by hand, it was quite impossible to comply with these conditions, all of which are necessary to good carding. Much ingenuity has been exercised in producing a *card-making machine*, which the writer had an opportunity of inspecting at the works of Messrs. Curtis and Co., at Manchester; but it would be impossible, in this little treatise, to give more than a general idea of this wonderful piece of mechanism. The leather is first prepared by a machine, which cuts it into sheets and fillets of the proper length and breadth; each fillet is wetted and stretched to its full extent, so as to produce an even surface; it is then passed between rollers, against a nicely-adjusted knife-edge, which shaves it down to a perfectly uniform thickness. The fillet is then wound upon a roller, and made to pass between two guide-rollers, to a receiving-roller above the card-making machine, when the fillet is held fast, and stretched by a clamp. The wire of which the teeth are to be made is supplied from a drum placed at the side.

Matters being thus arranged, the machine performs its work in the following order:—Two prickers advance, and make two holes in the surface of the leather; a pair of sliding pincers next seize the wire, and wind off from the drum a length exactly sufficient for two teeth; a tongue of steel holds this piece of wire exactly in the middle, while a knife advances and cuts it off from that part of the wire held in the pincers. Steel fingers next advance, bend the piece of wire just cut off, and carry it

forward to the holes previously made by the prickers. The points of the wire are seized on the opposite side of the leather, and a bar rises up and bends the two limbs so as to form a knee in each. A pusher then acts from the opposite side, and drives home the wire into the leather, which is then shifted by the guide rollers, and another wire is inserted as before.

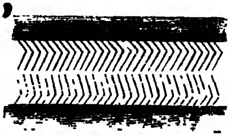
When this machine works at its ordinary speed, it is quite impossible to follow its various complicated movements, for it puts in two hundred teeth every minute, completing a length of twenty feet of card in a day; but the superintendent was so kind as to put the machine out of gear with the steam engine (which works ninety card-making machines in one room), and to turn it slowly by hand, whereby its beautiful movements were made intelligible. What adds apparently to the complexity of the machine, is the necessity of making cards for some purposes *ribbed*, that is, arranging the wires in lines crossing the fillet; while for other purposes the cards are *twilled*, that is, the wires form oblique lines across the fillet. When the cards leave this machine, all slight inequalities are removed by grinding; and the cards, when in use, are ground down from time to time, sometimes every day, until worn out.

The appearance of the cards, and their mode of action, will be understood from the following figure.

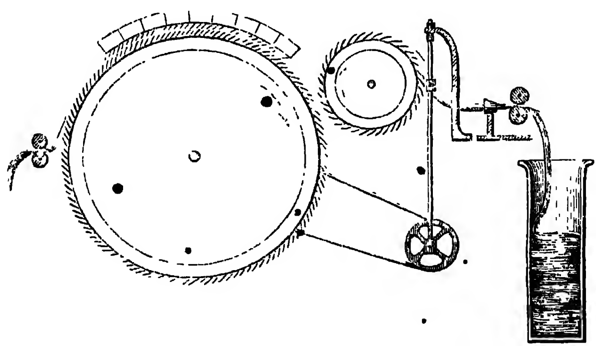


If these cards be moved in opposite directions with a tangled tuft of cotton between them, the fibres will be seized by all the teeth—those of the top card will pull them one way, those of the bottom another, by which means all the curls and twistings of the lock will be opened and drawn out, and the fibres made to lie side by side, or before each other. This effect may not be produced at once, but by repeatedly drawing one card over the other it will certainly be effected.

But in thus laying the fibres side by side, and end to end, each card takes up a portion of the cotton. To get the whole of the cotton upon one card, all that is necessary is to reverse the position of the two, and to place them shown in the opposite figure, where it will be seen that by drawing the upper card over the lower one, the teeth of the latter can offer no resistance, and thus it is stripped of its cotton.



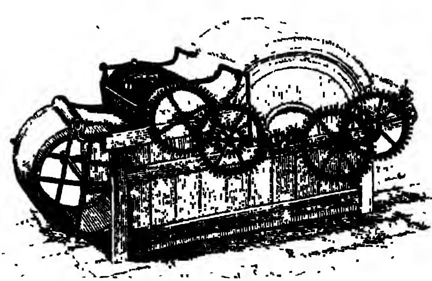
In the carding-engine this principle is carried out on a large scale. A drum about three or four feet



in diameter, and three or four feet in length, moving on a horizontal axis, is covered with narrow fillet cards parallel to the axis, a small space being left between the separate fillets. The upper part of the drum is covered with a concave frame, containing narrow cards, corresponding in form to those of the cylinder. The cotton lap is supported at one end of the engine upon a roller, which, by slowly turning, assists in unfolding it. As it becomes unfolded, it passes between two fluted rollers, which are pressed together by a weight hanging from the end of the upper roller. The cotton is then

caught by the wires of the main cylinder, the teeth of which, assisted by the cards of the frame-work, arrange the fibres of the cotton, as already explained. After this they are taken off by a second cylinder, called a *doffer*, which moves in a contrary direction, and from this the cotton is removed by a very beautiful contrivance, called the *crank and comb*.

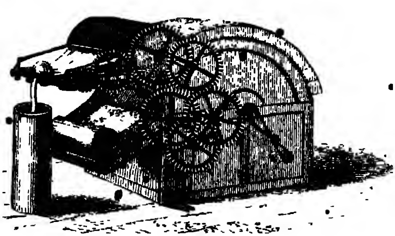
The inventor of the carding-engine is not known with certainty. It appears, however, that in 1748, Lewis Paul patented two different machines for carding, in one of which the cards were arranged on a flat surface, and in the other on a drum. The cards were arranged parallel to each other and to the axis of the drum, a space being left between every two cards. The wool was put on by hand, and the cardings were taken off separately by a moveable comb, the spaces between the cards regulating the substance of each carding. By this method the machines had to be stopped every time the cardings were taken off, and then had to be joined end to end to form the perpetual carding. The machine was not generally known and adopted in Lancashire for more than twenty years after the date of the patent. One of the first improvements was to fix to the



FIRST CARDING ENGINE.

machine a revolving cloth or feeder, on which a given weight of cotton wool was spread, by which it

was conveyed to the machine. Arkwright further improved this by rolling up the feeder with the cotton spread upon it, as already explained, and allowing this gradually to unroll to feed the cylinder. Another improvement brought off the carded wool in a continuous fleece, forming a uniform and perpetual sliver. The doffer, which strips the wool from the large cylinder, turned off a carding of no greater length than that of the cylinder; but it was found, that by entirely covering the doffer with narrow cards, wound round in a spiral form, without having any spaces, the wool might be brought off in one unbroken fleece. But the method of stripping off the wool from the doffer was attended with many difficulties, which were at length overcome by the invention of the crank and comb. A plate of metal, finely toothed like a comb, is worked by a crank up and down over the doffer, so that, by slight and frequent strokes on the teeth of the card, it strips off the cotton in a continuous filmy fleece, which, as it comes off, is drawn through a funnel at a little distance in front of the cylinder, which reduces it to a roll or *sliver*. This after passing between two rollers, and, being compressed into a firm, flat riband, falls into a deep can, where it is coiled up in a continuous length until the can is filled.



SECOND CARDING ENGINE.

The invention of the crank and comb has been given by some to Arkwright; by others to Har-

greaves, the inventor of the jenny. Those who defend the claim of the former, say that it was communicated to Hargreaves by one of Arkwright's workmen, who chalked out a sketch of it upon the table of a public-house.

Thus, by a series of ingenious improvements, the carding-engine was perfected, and it has scarcely been improved since Arkwright's time. It is interesting to watch the cotton at one end in its tangled, knotted state, the fibres lying in every direction, and then to walk to the other end and notice the beautiful filmy web stripped from the doffer by the crank and comb. It is so light and flimsy that it no longer resembles cotton, but rather the delicate lines which the gossamer spider sometimes draws over the fields in autumn.

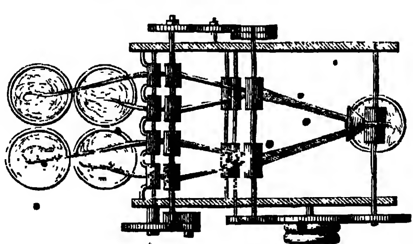
In fine spinning, the cotton passes through two carding-engines; the first is coarse, and called a *breaker-card*, and the second, in which the teeth are finer, called a *finishing-card*. A number of cardings from the breaker-card are united together at the edges by passing them between the steel rollers of a *lap-machine*; the new lap thus formed is wound upon a cylinder, and is then ready to feed the finishing-card.

DOUBLING AND DRAWING.

The fibres of the cotton are not yet sufficiently level to be twisted into yarn; and it often happens that the teeth of the card lay hold of a fibre by the middle, and thus double it together, in which state it is unfit for spinning. The cardings are therefore doubled and drawn out by a machine called the *drawing* frame, the principle of which depends upon different pairs of rollers revolving with different degrees of rapidity, as already noticed. If, however, the riband, as it leaves the carding-engine,

were simply extended in length by drawing it out, it would be liable to tear across, or to be of a different thickness at different parts of its length. To prevent the tearing, and to equalize the thickness, a number of cardings are joined together, and drawn out to a length equal to the sum of the lengths of all the separate cardings. The effect produced is the same as taking a piece of cotton-wool between the finger and thumb, and drawing it out many times, laying the drawn filaments over each other, before each drawing. If the cotton be then examined, it will be found that all the fibres are parallel, and of equal length. This effect is accomplished very perfectly in the drawing-frame, which consists of a number of rollers, arranged in what are called *heads*, each head consisting of three pairs of rollers, of which the second pair moves with greater speed than the first, and the third moves quicker than the second. Drawing rollers are used in several machines which have yet to be noticed; their arrangement and mode of action may therefore be further explained.

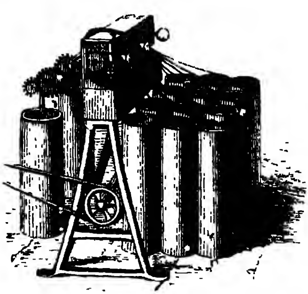
The accompanying figure represents the arrangement of one drawing-head. The under rollers are



made of iron and fluted; the upper ones, also of iron, are smooth, and covered first with flannel and then with leather. This enables the rollers to take firm hold of the cotton. The top rollers are sometimes called *pressers*, because they press, by means of weights, upon the under ones. These weights are

hung to a curved hook, or to a saddle, which includes two or more rollers. A mahogany bar, faced with flannel, rests, by its own weight, upon the top rollers, and strips off all the loose, hanging fibres. Similar bars are also made to press up against the under fluted rollers. The distance between the first and second pairs of rollers is never allowed to exceed the length of the cotton filaments, for if such were the case, the riband might be torn apart by the second pair pulling it while the first held it fast. The riband is stretched most in passing from the second to the third pair, the distance between which must not be too great, for the reason just stated, nor too small, or the staple will be torn.

The cardings are sometimes presented to the drawing-frame in the form of laps, or more usually they are taken up from separate cans, and guided over a tin or brass plate containing a number of separate channels. They all meet and unite together just before passing between the first pair of rollers, which reduces them all into one sliver; the second pair extends every inch of this compound sliver into about two inches, and the third pair of rollers extends these two inches into ten: so that, suppose ten slivers from



DRAWING. (12 INTO 1.)

ten separate cans enter the frame on one side, the result is, that, after passing through the rollers, a single sliver is produced of the same thickness as one

of the ten slivers, but of ten times the length; the ten slivers are, in fact, united into one, and this being passed between two smooth cast-iron rollers, to condense it, is allowed to fall into a can on the opposite side of the frame.

By repeating this process again and again, it will be easily seen that the chances of uniformity in the sliver are greatly multiplied; for the defects of individual slivers are absorbed and got rid of. When ten of the cans are filled with the compound sliver, they are passed on to a second drawing-head, and the ten *drawings,* as they are now called, are again doubled, and drawn out into one. Twelve of these are then doubled, and drawn out at a third head; twelve of these are doubled again, and again drawn out at a fourth head; and, lastly, six of these are doubled, and drawn out at a fifth head.

Thus it will be seen, that, by collecting all these numbers together, the doubling of the fibres of the cardings have been multiplied no less than 86,400 times; for $10 \times 10 \times 12 \times 12 \times 6 = 86{,}400$. The drawing is carried to this extent only in fine spinning. For coarse numbers, the doubling and drawing are not repeated so often. Six card-ends are usually passed through the first drawing-head, and formed into one riband. Six of these ribands are again formed into one; six of these again make a third sliver, and five of these pass through the last drawing-head. Thus we have $6 \times 6 \times 6 \times 5$, or 1080 of the original card-ends united in the finished drawn sliver.

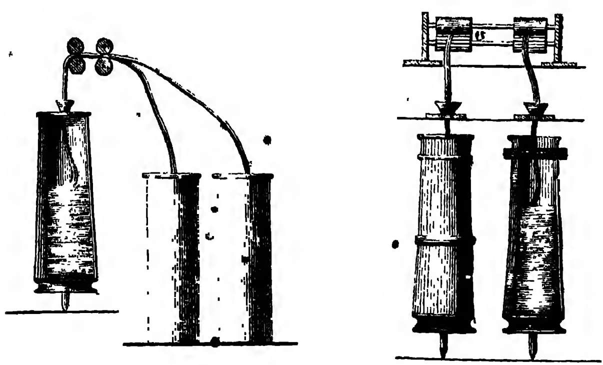
This doubling and drawing process is of the greatest importance, the quality of the yarn depending upon its being well done. Arkwright is the inventor of it; and it is related of him, that, when any defects appeared in his yarns, he told his people to look to their drawings, for, if they were right, every thing else would be so too.

The drawing-frames require constant watching, to

see that none of the cans are emptied before full ones are ready to supply their place.* The labour is performed by young women, who are kept pretty actively at work. A contrivance has been introduced which greatly abridges the labour. A cylindrical plunger is made to fall at intervals into the receiving-can, and, by pressing down the sliver, enables the can to hold a much greater quantity than it would do if the sliver were left to fall loosely into the can. Further improvements have lately been made, by which the sliver is regularly and beautifully coiled in the can, and compressed at the same time, but without at all stretching the sliver.

ROVING.

By the process of doubling and drawing, the cotton is formed into a loose porous cord, the fibres of which are arranged side by side. This cord is still much too thick for yarn, but it cannot be reduced in size

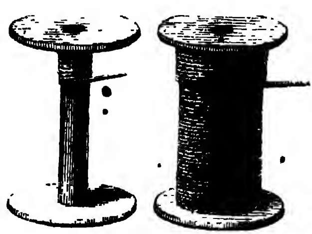


by drawing merely, for if this were attempted it would break; a slight twist is therefore given, which, by condensing the fibres, allows the drawing to pro-

* By a recent invention, in case of the breaking of any sliver, or the emptying of a can, so as to lessen the number of the slivers, the machine is made to stop instantly; thus requiring much less attention, and insuring a greater uniformity in the thread.

ceed. This is the commencement of the spinning process (which is, in fact, little more than a combination of drawing and twisting), and is called *roving*. Up to a recent period, the roving-machine, as introduced by Arkwright, was in use, but it is now superseded by better and more complicated mechanism. The roving-machine of Arkwright did not differ greatly from the drawing-frame. It consisted of two pairs of drawing-rollers, for extending the slivers, of which two were generally doubled and united. The sliver, as it quitted the drawing-rollers, was received into a can, which was made to spin rapidly round, and this, by giving a slight twist to the sliver, formed the roving, and distributed it in a coil within the can. Thus far all was well, but it was necessary for the next process that the roving should be wound upon bobbins; the can, when full, was therefore carried to a simple machine, and wound by hand, by which it was scarcely possible to avoid injuring the delicate cord, and hence the quality of the yarn suffered. This led to the introduction of the *Jack frame*, or *Jack-in-the-box*, as it was more familiarly called, and afterwards to the *bobbin-and-fly frame*, which may now be considered as the established roving-machine of the cotton manufacture.

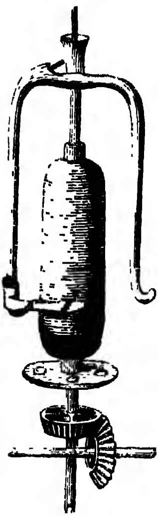
The bobbin-and-fly frame is an exceedingly complicated machine, although the objects to be accomplished by it are sufficiently simple; namely, to give the roving a slight twist, and then to wind it on the bobbin. The first is easily done by the revolutions of the spindle; the second is more difficult. It is scarcely necessary to explain, that the bobbins now under notice differ in no way



BOBBINS.

from the reels in common use, except in being of very

large size. The spindle, which holds the bobbin, is a round steel rod, driven by a small cog wheel, fastened on the lower part of the spindle, as shown in the next figure. The bobbin is slid upon the spindle, and the small bed, or platform, on which it rests, is made to revolve by another series of small wheels, not shown in the figure. The spindle has two arms, called the *fly* or *flyer*. This fly is fixed on the top of the spindle in such a way, that it can be taken off in an instant, for the purpose of putting on or taking off the bobbin. One arm of the fly is hollow, the other solid, and this serves to balance the machinery. One machine contains from thirty to a hundred and twenty spindles, which, for economy of space, are placed in two rows, each spindle in the back row standing opposite the space left between two spindles of the front row.



The action of the machine is this: The sliver having been drawn by the rollers, is twisted, by the rapid revolutions of the spindle, into a soft cord or roving: this enters a hole in the top of the spindle, and passes down the hollow arm of the fly; it is then twisted round a steel finger, which winds it on the bobbin with a certain pressure. This spring finger is a beautiful contrivance by Mr. Houldsworth. Before this invention, the rapid motions of the fly caused the roving to become improperly stretched by the centrifugal force, but this is now prevented by twisting the roving round the finger: by its pressing the soft roving on the bobbin, each bobbin is made to hold a much larger quantity.

All this seems to be sufficiently simple; but the difficulties begin to appear when it is considered, that the delivering finger must move up and down, so as

to wind the roving evenly over the bobbin, and that, as the bobbin increases in thickness, a difference in speed is necessary to prevent the roving from being improperly stretched or broken. The first object is attained by making the bobbin slide up and down on the spindle, and the second by causing the strap which drives the bobbin to act on a conical instead of a cylindrical drum; thus giving to the movement a varying instead of an equal degree of speed.

It will be seen, that the spindle and bobbin are driven by different movements. This is necessary, because, if they both moved at the same rate, the roving would be twisted merely, and not wound upon the bobbin; but, by making the bobbin revolve a little quicker than the spindle, the winding is accomplished. For example, if the bobbin revolves fifty times, while the spindle only revolves forty, forty turns of the bobbin will have nothing to do with winding; but there are ten turns of the bobbin above those of the fly, which will perform the winding. Hence, the forty turns of the spindle produce twist, while the fifty turns of the bobbin produce ten coils of the roving upon its barrel.

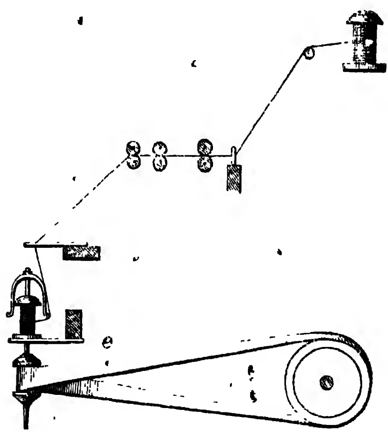
In fine spinning, two rovings are doubled and passed a second time through the frame, where they receive a further degree of drawing and twist.

The bobbin-and-fly frame is superintended by a female, whose duty it is to join the broken slivers, to remove the full bobbins, and to place empty ones in their stead.

In fine spinning, the rovings are sometimes prepared at what is called the *stretching-frame*, which is a kind of mule-jenny, to be noticed presently; but usually the rovings are finished at one of two machines, namely, the *throstle* and the *mule-jenny*. It may be stated, as a general rule, that the throstle spins warp, and the mule weft; there are, however, many exceptions to this.

THROSTLE SPINNING.

It has been already noticed, that Arkwright's water-frame was partially superseded by the mule-jenny, but that, as it was capable of producing a strong wiry thread, well adapted for warps, it was introduced in an improved form, under the name of the *throstle*. This machine is usually made double, a row of bobbins, spindles, &c. occupying each side of the frame. The bobbins, filled with rovings from the bobbin-and-fly-frame, are mounted at the upper part of the frame in two ranges. The roving from each bobbin passes through three pairs of drawing-rollers, where it is stretched out to the requisite fineness. On quitting the last pair of rollers, each thread is guided by a little ring, or a notch of smooth glass let into the frame, towards the spindles, which revolve with great rapidity, producing, by the motion of their flyers through the air, a low musical hum,



which is supposed to have given the name of *throstle* to this machine. The roving, which may now be called *yarn*, passing through an eyelet formed at the end of

one of the arms of the flyer, proceeds at once to the bobbin.

The yarn is wound upon the bobbin by a curious contrivance. The bobbin fits very loosely upon the spindle, and rests on its end upon a kind of platform. The bobbin is not connected with the spindle except by the thread of yarn which has to be wound; therefore, as soon as the flyer is set spinning, the thread drags the bobbin after it, and makes it follow the motion of the spindle and fly; but the weight of the bobbin, and its friction on the platform, which is promoted by covering the end with coarse cloth, causes it to hang back; and thus the double purpose is served of keeping the thread stretched and winding it on the bobbin much more slowly than the flyer revolves. The yarn is equally distributed on the bobbin by a slow up-and-down motion of the platform.

These effects are the same as were produced by the bobbin-and-fly frame, but in the throstle they are attained by simpler means. In the former machine, a distinct movement caused the bobbin to revolve quicker than the spindle. In the throstle, the bobbin is made to revolve by the pull of the yarn, which is now sufficiently strong for the purpose; but the roving in the bobbin-and-fly frame would not bear the strain.

A throstle-frame generally contains from 70 to 150 spindles on each side. The drawing-rollers extend the whole length of the frame. The top rollers are, as usual, covered with leather, and the thread passes over a guide bar, which has a slight horizontal movement, for the purpose of leading the thread over different points of the rollers, and thus preventing the leather from being chafed by constant pressure on one spot. One young woman, and an assistant, attend to from 140 to 300 spindles in two double frames; their duties are to mend broken threads, and shift the bobbins as required.

MULE SPINNING.

The throstle is not often employed for very fine spinning, because fine yarn would not bear the drag of the bobbin; but in mule spinning the yarn is wound at once upon the spindles without any strain. In the mule the roving is first drawn by the usual system of rollers, and then stretched by a moveable carriage, as in the spinning-jenny of Hargreaves. The effect of first drawing and then stretching, is to make the yarn finer and more uniform, as will be explained presently. The spinning-mule is the most interesting and impressive spectacle in a large cotton mill; on account of its vast extent, the great quantity of work performed by it, and the wonderful complication and ingenuity of its parts.

The spinning-mule consists of two principal portions; the first, which is fixed, contains the bobbins of rovings and the drawing-rollers; the second is a sort of carriage, moving upon an iron railroad, and capable of being drawn out to a distance of about five feet from the fixed frame. This carriage carries the spindles, the number of which is half that of the bobbins of rovings. Motion is given to the spindles by means of vertical drums, round which are passed slender cords, communicating with the spindles. There is one drum to every twenty-four spindles.

The carriage being run up to the point from which it starts in spinning, the spindles are near to the roller-beam: the rollers now begin to turn, and to give out yarn, which is immediately twisted by the revolution of the spindles; the carriage then moves away from the roller-beam, somewhat quicker than the threads are delivered, so that they receive a certain amount of stretching, a circumstance which gives value to this machine. The beneficial effect is produced in this way: when the thread leaves the rollers it is thicker in some parts than in others, and those

thicker parts, not being so much twisted as the thinner ones, are softer, and yield to the stretching power of the mule, so that the twist is equalized throughout, and the yarn becomes more uniform. When the carriage has *completed a stretch*, or is drawn out from about 54 to 64 inches from the roller-beam, the drawing-rollers cease to give out yarn, but the spindles continue to whirl until the threads are properly twisted. In spinning the finer yarns, the carriage sometimes makes what is called a *second stretch*, during which the spindles are made to revolve much more rapidly than before. The drawing, stretching, and twisting of a length of thread being thus completed, the mule disengages itself from the parts of the machinery by which it has hitherto been driven, and the spinner then seizes the carriage with his left hand, and pushes it back to the roller-beam, turning at the same time with his right hand a fly wheel, which gives motion to the spindles. At the same time a *copping* wire, as it is called, is pressed upon the threads by the spinner's left hand, and they are thus made to traverse the whole length of the spindle, upon which they are then wound or *built* in a conical form, which is called a *cop*. These cops are used for placing in the shuttle in weaving, and form the weft, or short cross threads, of the cloth.

One man is able to attend to two mules, guiding in the carriage of one mule by hand, while the carriage of the other is being moved out by the steam-engine. Much skill is required in pushing back the carriage. As a preparatory step, the spinner causes the spindles to revolve backwards for a moment, to slacken the threads just completed, and throw them off the points of the spindles previous to winding them. In pushing the carriage back he must attend to three things:—he must guide the copping wire so as to insure the regular winding of the yarn on the cop; he must regulate the motion of the spindles; and he must push the carriage at such a

rate as to supply the exact amount of yarn that the spindles can take up in a given time.

The spinner is assisted by boys or girls, to piece the broken threads. He also employs a *scavenger* to collect all the loose or waste cotton, called *fly*, which lies on the floor, or hangs about the machinery. This is chiefly used in cleaning the machinery. It is calculated that the waste of material from the different machines in spinning cotton, amounts to $1\frac{1}{2}$oz. per lb. or nearly one-tenth of the original weight. It is the duty of the piecer to join the broken ends of the threads as the carriage moves from the upright frame. The breaking of the threads depends, in some degree, on the temperature and the state of the atmosphere. During an east wind the threads sometimes break faster than the piecers can join them; and it seems probable that the rapid whirling of so many thousand pieces of machinery produces, in very dry weather, a large amount of electricity, which may prevent the proper spinning of the fibres. At such times it is not uncommon to keep the atmosphere of the room moist, by jets of steam, and to maintain a temperature of from 68° to 76°. Indeed, fine yarn cannot well be spun at a lower temperature.

The quality of the yarn in mule-spinning depends upon the care and attention of the spinner, and it was long thought impossible to substitute mechanical contrivances for the work performed by him. This has led the spinners, on many occasions, to league together, for the purpose of compelling their masters to grant such wages as they chose to demand, and to accept such an amount of labour as they chose to give. Such acts as these, which are in direct violation of the Divine command, "Servants, be obedient to your masters," are sure, sooner or later, to meet with punishment; and such has been the case in the present instance. The mill-owners, feeling that no dependence was to be placed on their spinners, long

desired to supersede them by mechanical contrivance; and this at length, after numerous failures, has been done in a complete manner by the invention of the *self-acting mule*, or the *iron man*, as it is sometimes called in Lancashire. Mr. Roberts, of the celebrated firm of Sharp and Roberts, machine-makers, succeeded in perfecting this extraordinary machine, which not only does the work of the spinning-mule without the assistance or attendance of any one except the little piecer, but does it in a more perfect and complete manner; and produces a larger quantity of yarn. The cops, also, are firmer, and of better shape, and contain a much larger quantity of yarn than cops of equal size wound by hand, so that they are less liable to injury; and in weaving, the superior firmness of the cop allows the loom to be worked at greater speed, whereby cloth of superior quality is produced in greater quantity.

REELING.

The yarn is now disposed of in various ways, according to the use for which it is intended: but it is often found convenient to make it up into hanks.

The machine for winding the yarn from the bobbins, or cops, into regular hanks, is a long eight-sided frame, mounted on a carriage, which is also furnished with spindles or skewers, for holding the bobbins, or cops. These frames are managed by young women, whose duty it is to turn the reel until a check is struck. They then know that the reel has made eighty turns; and, as the sides of the reel measure one yard and a half, a *ley* or *rap* is thus formed, containing 120 yards. Seven of these raps make one hank, containing 560 threads of a yard-and-a-half each; thus making 840 yards to the hank. The size of the yarn is ascertained by weighing the hanks in

a kind of balance called a quadrant.* Each size is put up separately in cubical bundles of five or ten pounds weight. These packages are closely com-

pressed by a simple but ingenious machine called the *bundling-press*, where they are firmly tied while under pressure, and, being wrapped neatly in paper, are ready for the market. The usual average number of hanks to the pound is, for coarse spinning, from ten to forty, but, for some purposes, such as candle-wicks, coarse counterpanes, &c., as low as two hanks to the pound are made. It is often exported as low as from four to six hanks. The highest number usually obtained in fine spinning is 300, but the writer saw at Mr. Houldsworth's mill, at Manchester, yarn of which 460 hanks were required to make a pound. This yarn is a beautiful, hard, cylindrical cord, of wonderful fineness, and has been sold for *twenty guineas*, or upwards, a pound, an astonishing example of the effect

* Tables are published for ascertaining the number of hanks to the pound; but the following is not an uncommon mode of ascertaining. 1,000 grains divided by the number of grains in a ley, gives the number of hanks per pound. This rule is founded on the fact that a ley is $\frac{1}{7}$th of a hank; and 1,000 grains is equal to $\frac{1}{7}$th of a pound.

of well-directed industry, in increasing the value of raw material. A pound of the best sea-island cotton is worth, at the highest price, 5*s.* per pound; when manufactured into yarn of the number 460, the value of this pound of cotton is 420*s.*, or, in other words, its value is increased 84 times. This yarn was produced by Mr. Houldsworth for a muslin dress for Her present Majesty, in order to show the capabilities of the British manufacture, far excelling any thing produced by the Hindoo spinner. It is scarcely necessary to say, that such yarn is not commonly made, but that, if a demand for it were to arise, it could be supplied at a gradually decreasing price.

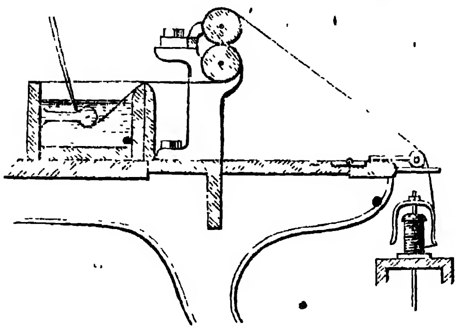
THE MANUFACTURE OF SEWING THREAD.

When the yarn is completed, it is usually sent to the *doubling and twisting mill*, for the purpose of being converted into what is now properly called thread. Although we are accustomed to apply the word *thread* to a thin, narrow line of any fibrous material, the manufacturer limits the term to that compound cord produced by doubling or twisting two or more single lines. The single line he calls *yarn*: two or more single yarns laid parallel, and twisted together, he calls *thread*; and of this there are many varieties, such as *bobbin-net-lace thread, stocking thread, sewing thread*, &c.

The writer visited a sewing-thread factory at Manchester, which, though inferior in extent and importance to the cotton mills, where the raw material is converted into yarn, presents, nevertheless, several points of interest.

The yarn, which is received at the factory in the form of cops, is wound upon large bobbins, ready for the doubling-mill, or *thread-frame*, as it is sometimes called. This machine is not unlike the throstle of the cotton-spinner, already described; but its

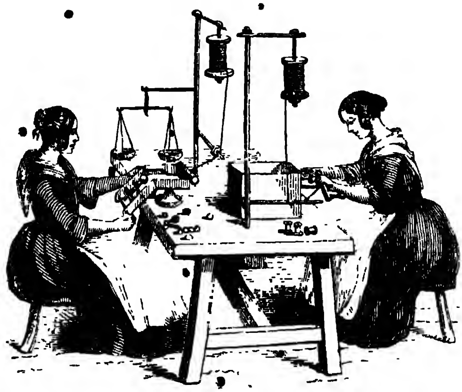
action will be better understood by reference to the following cut. The cops are mounted loosely upon



spindles or skewers, on a *creel* or shelf extending the whole length of the room; as the yarn is unwound, it is led across a glass rod, and made to pass into a leaden trough filled with water, or a weak solution of starch, which enables the lines of yarn to twist together into a more solid thread. On quitting the trough, the lines of yarn (two, three, four, or six in number, according to the desired size of the thread) are guided over a roller whereon they are laid parallel, and then made to pass down to the spindle, the rapid revolutions of which twist these parallel lines together into a solid cord or thread. The twist is given in an opposite direction to that applied by the spinning-machine, and when the thread is completed, it is then wound upon the bobbin which surrounds the spindle.

The thread is now wound into hanks for bleaching or dyeing (two important processes, which will be noticed in a separate treatise). The hanks of bleached or dyed thread are wound on bobbins, for the purpose of *balling* or *reeling*. The process of forming the thread into balls or reels, is performed by young women with an almost magical celerity. Each young woman is seated at a kind of turning-lathe; she

seizes the end of the thread, and attaches it to a rod of steel, sets this spinning, and in an instant a ball of cotton appears at the end of the rod; the rotation



BALLING AND REELING.

is stopped, a blue ticket is inserted at the end, a further quantity of thread wound to secure the ticket, and the ball is finished. The size of the ball is regulated with extreme accuracy by the eye. The number of balls to the pound varies from 16 to 600; and the young woman being told to produce a certain number to the pound, makes a few, weighs them until she has got the exact size by weight; after this she relies entirely upon her eye, and so accurate is her judgment, that the variation of the balls in weight is very trifling. The cotton is wound on reels with the same surprising celerity; the steel finger which delivers the thread from the bobbin, being guided to and fro to distribute it equally along the barrel of the reel. The quantity here also is judged of by eye, and varies from 30 to 300 yards in each reel. As each reel is filled, the broken end of the thread is inserted in a notch, which the

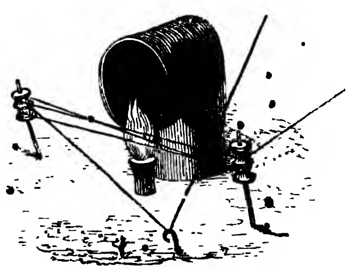
winder cuts for the purpose. Reeling is not such rapid work as balling, but is still sufficiently swift to prevent the eye from following the motion of the thread. The chief delay in both cases arises from the breaking of the thread, which, during the writer's visit, occurred rather often.

The reels are placed on end in a kind of shallow drawer, and little children cut out and paste on the labels. These labels are printed on sheets, and the back of each sheet is covered with gum, like the postage-stamps. The children stamp out the labels with a circular punch, wet the back of each against the tongue, and then press the wetted side against the end of the reel. Some idea may be formed of the extent of this business, from the fact, that a sheet, containing 144 labels, printed in blue and gold, and glazed, and then covered on the back with a layer of gum, is sold for one penny. The smallest bronzed cotton bobbin labels are sold as low as one halfpenny per gross. The writer paid a visit to the extensive establishment of Messrs. Bradshaw and Blacklock, of Manchester, where these labels are produced in large quantities. Each sheet, which is of a purple colour on one side, and plain on the other, is first printed from a copper-plate in an invisible adhesive ink; the sheet, immediately it is printed, is taken by a boy, who rubs over it, with a hare's foot, a yellow impalpable metallic powder, which passes for gold, but is really copper or bronze in a minutely divided state. The powder adheres to the printed letters and border, and is brushed off from the parts where no ink has been applied. The sheets, when perfectly dry, are hot-pressed, or calendered, which gives the glossy surface, and then covered on the plain surface with gum; when this is thoroughly dry, the sheets are pressed again, and are then ready for sale. Letter-press and copper-plate printing, as well as lithography, are all extensively used in producing labels and tickets.

The balls of cotton are tied up in small flat bundles, each containing a quarter of a pound; the proper number is counted out, folded up in paper, and tied into a bundle, with the remarkable speed and precision which is attained only by long practice: four of these quarters are next tied up into pound parcels, which, after being labelled, are ready for the wholesale market.

SINGEING THE THREAD.

In fine spinning, the yarn, when doubled, is, for some purposes, *singed* or *gassed*, in order to get rid of the loose fibres, and to make it more level and compact. The process of singeing yarn strikes a stranger as being more remarkable than anything else in the mill. In a long room in the upper part of the mill, or in a shed attached to it, are several tables, lighted up with a large number of jets of flame, about twelve inches apart, producing a singular but pleasing effect. Above each flame is a little hood or chimney. On entering



GASSING THE YARN.

this room the smell of the burnt cotton is immediately perceived, and, on approaching the table, one is surprised to see a fine, delicate thread crossing each

flame in two or three directions, and apparently at rest; but, on following the course of this thread, it is found to proceed from one bobbin, which is rapidly spinning round, and to pass through the flame to another bobbin, which is also in rapid motion. It is then seen that the thread is also moving at a rapid rate, by which means alone does it escape being consumed. The thread is led over pulleys, so as to pass two or three times through the flame, which singes off the loose fibres, converting them into a reddish powder or dust, which, if blown about and inhaled, would do great injury to the lungs: this is why the gassing-room is in a remote or retired part of the building, to prevent the air being disturbed by the bustle of the busier parts.

After the thread has been singed, it passes over a brush, to clean it, and then through a small hole or notch cut in a projecting piece of brass, which is ingeniously made to detect any knot or foul point in the thread. The hole is so small, that there is but just room for the thread to pass; if, therefore, a knot or other impediment occurs in the thread, the piece of brass is depressed, and this is connected with mechanism which suddenly turns the gas flame aside, and lifts the bobbin off the rotating barrel which turns it, causing the whole to stop. The thread remains at rest until the attendant, called the *tenter-woman*, mends the defect, and sets the bobbin in motion again. The advantage of this contrivance is, that no time is lost; for, while the defective thread stops, all the rest go on as usual. The effect of singeing is to raise the yarns to a higher number, by the diminution of their weight per hank. Thus, No. 90 will become No. 95; so that there is an actual difference of five hanks per pound by the operation of gassing.

STATISTICS.

THE statistics of the cotton trade will be better understood, when the important subjects of weaving, bleaching, dyeing, and printing, are completed; but a few details respecting cotton-wool, yarn and thread, may be interesting in this place. The amount of cotton-wool imported into England in 1845, amounted to 659,584,477 lbs., of which, 44,363,355 lbs. were exported, leaving a quantity for home consumption, amounting to 615,221,122 lbs. By far the greater part of this supply came from the United States of America. For some years past, the cotton-wool imported from foreign possessions paid an import duty of 2*s.* 11*d.* per cwt.; that from British possessions paid only 4*d.* per cwt. From the 22d of March 1845, this duty was wholly repealed.

In 1845, the prices of cotton-wool at Liverpool, were as follows:—Sea Islands cotton-wool from 10½*d.* to 16*d.* per lb.; Uplands, 5⅜*d.* to 4½*d.*; Orleans, 5¼*d.* to 6*d.*; Egyptian, 5½*d.* to 10*d.*; common West Indian, 4*d.* to 5*d.*; Surat and Madras, 2½*d.* to 3⅜*d.*

The quantity of cotton-yarn spun in England and Scotland in 1845, was as follows:—

	lbs.
In England	467,029,465
In Scotland	27,737,022
Total	494,766,487

The quantity of cotton-yarn exported from England in 1845, amounted to 131,937,935 lbs. Of this quantity, the principal portions were distributed as follows:—

	lbs.
The Hanse Towns, &c.	40,315,592
Holland	21,556,043
Russia	18,167,962
India	14,116,237
China	2,402,750
Sardinia, Tuscany, &c.	4,482,539
Belgium	3,917,267

The remainder was sent in much smaller quantities to various parts of the world.

The quantity of cotton-thread exported in 1845, amounted to 2,567,705 lbs.

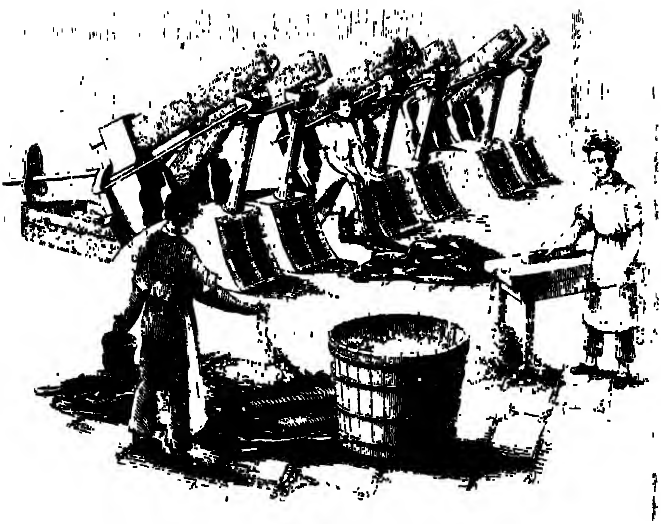
The total weight of yarn in manufactured cotton-goods exported from England in 1845, amounted to 336,866,327 lbs.; the total value of which was £22,063,898.*

Much has been said respecting the health of the operatives in cotton-mills. Children under thirteen years of age are now under the protection of the legislature; they are allowed to work only half time, that is, six hours a day; and they must attend school during some portion of the day. An excellent school, frequently under the inspection of the Committee of Council on Education, is attached to a large number of factories; and unless the children attend this every day, they are not allowed to work in the mill. It is generally arranged that those children who work during the morning attend school in the afternoon, while those that work in the afternoon go to school in the morning.

The writer was agreeably disappointed to find that the work-people in the mills had by no means that sickly appearance which he had been led to expect. On the contrary, many of the younger females were stout, healthy looking girls, and others, though not ruddy, were lively and active in their movements, and in their expression of countenance. There were no symptoms of suffering or disease among the young people in any of the mills visited by the writer. Perhaps the most trying operations in the cotton-mill are *willowing*, *batting*, and *carding*. The rooms in which they are carried on are clouded with fine particles of cotton, which sometimes set a stranger coughing immediately on entering; this is probably injurious to the work-people. Most of the men

* The above statistical facts are stated on the authority of *Burn's Commercial Glance*. Manchester, 1846.

in these rooms were pallid in their complexions, and, though from habit they are not subject to the same inconvenience and difficulty of breathing which strangers suffer, there are evident marks of a languid state of health in the countenances of some. In judging from their appearance, however, it is necessary to make due allowance for an artificial whiteness, produced by the particles of cotton, which settle abundantly on their faces and hair.



FULLING STOCKS

THE USEFUL ARTS

AND

MANUFACTURES OF GREAT BRITAIN.

THE MANUFACTURE OF WOVEN GOODS.

PART IV.

THE MANUFACTURE OF WOOLLEN CLOTH.

THE processes by which wool is converted into woollen and worsted yarns have been detailed in a former treatise. Worsted stuffs, whether plain or twilled, are, for the most part, complete and fit for the market as soon as they are woven; but when woollen cloth is taken from the loom, it requires a number of curious and elaborate finishing processes, which must now be described.*

There is nothing that calls for particular remark in the weaving† of woollen yarn, except the large size of the looms, which allow of broad cloth, upwards of twelve quarters wide, being woven. This great width is necessary to allow for the shrinking which it undergoes in scouring and fulling. A cloth required to be sixty inches wide when finished, must be woven of the width of about one hundred inches.

* The writer has again to acknowledge the liberal assistance to himself and the artist, furnished by Messrs. John Brooke and Sons, of Armitage Bridge, near Huddersfield.

† For the details of weaving the reader is referred to a previous Treatise on the Manufacture of Woven Goods.

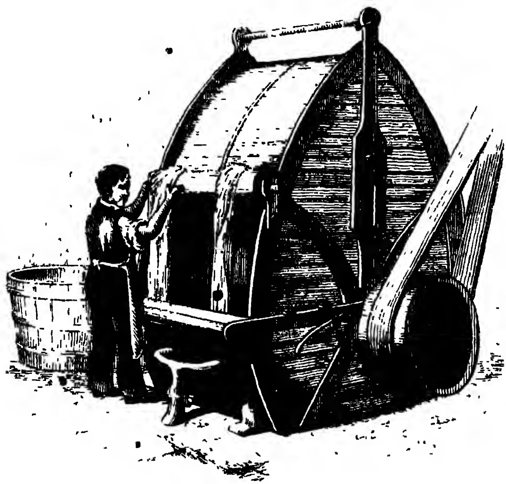
The cloth is furnished at the loom with outer edges of list for receiving the tentering hooks when it is stretched out to dry. In the West of England this list is made of goat's hair, and in Yorkshire of coarse yarn. In this, as in every other description of weaving, the power loom is rapidly superseding the hand loom.

SCOURING.

In the preparation of the wool for spinning, a quantity of oil is employed, which, together with the size used for the dressing, is left in the cloth when the piece is received from the loom. In this state it is greasy and rough, and the object of the processes about to be described, is to give it a smooth and level surface. The oil and size must first be got rid of, for which purpose the cloth is scoured at the *fulling mill*, which is a somewhat rude machine—supposed to stand, in point of antiquity, next after the corn or flour mill. Scouring consists in constantly agitating and exposing new surfaces of the cloth to the action of water containing some detergent substance. During many centuries a kind of clay, called *Fullers' earth*, was used for the purpose. It is found in great abundance in several parts of England, especially in Bedfordshire, Berkshire, Hampshire, and Surrey. Its value depends upon the affinity which the alumina contained in it has for greasy substances; but it is much less used than formerly, and only preparatory to scouring with soap.

The fulling-mill consists of two or more ponderous oaken mallets, working in a *stock*, as the frame of the mill is called. The mallets are worked by *tapit* wheels, the rims of which are furnished with projections, which, bearing upon the shanks of the mallets, raise them to a certain height, and then, suddenly releasing them, allow the heavy heads to fall by their own weight. The cloth is exposed to

the action of the mallets in an inclined trough, the end of which is curved, so that the cloth is turned round and round by the action of the stocks, and every part by turns exposed to them. When sufficiently beaten, a stream of hot water is allowed to flow through the trough until the cloth is perfectly clean, or the cloth is taken to a scouring machine, and



SCOURING MACHINE

washed in hot water with the assistance of squeezing rollers.

FULLING.

After the cloth has been scoured, the naked threads are very perceptible; it is then placed in the fulling-mill, and fulled for many hours, the object being to produce such a motion among the fibres of the wool, that their minutely jagged surfaces may lock into each other, and form not a woven tissue like calico or linen, but a *felted* mass similar to paper.

In a piece of thick fulled cloth the separate threads are almost lost under the thick fulled surface which is raised upon them: and the chief object of spinning and weaving seems to be to distribute the fibres equally, and to give strength to the fabric, rather than any particular character of woven goods. Indeed, during the last half century, several attempts have been made to produce cloth by fulling only, without the aid of weaving. There are a few factories now in operation which produce an excellent felted cloth fit for carpets, and the production of superfine broad cloth by the same means does not appear impossible.

The fulling stocks resemble the scouring stocks, but the trough has a square instead of an inclined end, so that the cloth receives the direct stroke of the mallets, and is not turned round and round as in scouring. A large number of these stocks are contained in one long room upon the ground-floor, and the continual thumping which is going on from the ponderous mallets has a very odd effect. It seems astonishing how the cloth can escape being pounded to dust, or at least worn into fragments; but the cloth is not injured on account of the number of the folds, and the directness of the blow, which falls with much greater force than in the scouring stocks.

The old fulling-mill was constructed of wood, but it is now usually of iron, and all the parts are fitted and adjusted with great care. The trough is sometimes made hollow, so as to form a steam-chest connected by a pipe with the boiler, for maintaining the degree of heat most favourable to the felting process. There is also a contrivance for altering the form of the trough so as to vary the force with which the mallets fall upon the cloth, different qualities often requiring different degrees of force. This is accomplished by a moveable curved plate, traversing on a fixed hinge-rod at the bottom of the trough: the upper end of

this curved plate admits of being advanced towards or withdrawn from the mallets, by means of a screw rod attached to its back.

Soap is employed in this process, about six pounds being required for a piece of coloured cloth containing from forty to fifty yards. White cloth fulls more easily than coloured, and in less time; and it requires less soap. The soap is first converted into shavings for the purpose of easier solution, and then one-half of it is dissolved in two buckets full of hot water. A portion of this is distributed over the cloth by pouring it in a fold near one of the ends; the man then takes up this fold and pulls out the cloth so as to form a sort of channel, along which the solution of soap flows, until the cloth has absorbed it all; he then adds another quantity, and pulls out the cloth as before.* The cloth is next put into the trough of the mill, and fulled for three hours. It is then taken out and stretched; and immediately returned to the trough without any fresh soap, and fulled for two hours longer. It is again taken out and the second half of the soap is distributed at four different times over the cloth, taking it out every two hours to be stretched, and to get rid of wrinkles. At the end of twelve hours a stream of clean water is admitted to wash away the soap, or the cloth is again passed through the scouring machine. The piece is then taken out, and dried. The effect of fulling is to reduce the piece in breadth about two-fifths, and in length one-third.

TENTERING.

The old method of drying, which is sometimes still adopted, is to stretch the cloth, by means of tenter-hooks, upon a long frame of wood, in an open

* See Frontispiece.

field, called the *tenter-ground*. The drying is now usually carried on more expeditiously in a room heated by steam pipes, the tenter-frame being used as in the open air. In stretching the piece on the tenter-frame it is drawn out about two yards in forty, but very little in breadth.

BURLING.

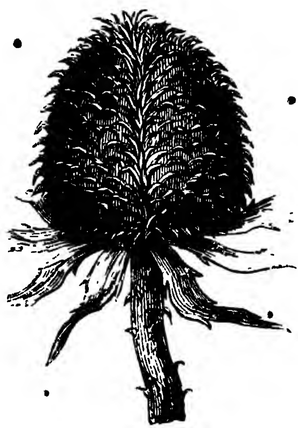
The operation of burling sometimes takes place immediately after scouring or fulling. A number of young women, called *burlers*, carefully examine the cloth on the surface, and through the web, against a strong light; and pick out with metal tweezers all knots, hairs, and dirt. This supervision is called *burling*. In large factories a room is set aside for the purpose; but it is sometimes done at the cottagers' houses, or, during the summer months, in the open air on walls or hedges.

TEAZLING.

The next process is *teazling*, by which the loose fibres of the wool are raised to the surface, so as to form, when properly cut or sheared, that beautiful pile or nap, which is so much admired in superfine cloths. This operation is performed by means of the prickly flower heads of the teazle, a species of thistle (*Dipsacus fullonum*), which is cultivated in the clothing counties for the purpose.* It is a biennial plant, and is sown in drills on strong land; it is thinned out by the hoe, and kept clear from weeds during the first year; in the second year it ought to be kept clear of weeds, although the same attention is not generally paid to hoeing as during the first. When the heads are ripe they are cut and dried for sale. There is some difficulty in drying them on account

* The Wild Teazle (*Dipsacus sylvestris*) is regarded by some botanists as a variety of the Clothier's Teazle.

of the care required to keep the heads uninjured. The cultivation of this plant requires so much attention, and the crop is so uncertain, that few manufacturers grow their own teazles. A continuance of damp weather will cause the heads of the plant to decay before they are ripe, rendering them totally unfit for the manufacturer. In Yorkshire the average



THE TEAZLE. (*Dipsacus fullonum.*)

price of a pack of teazles containing 13,500 large heads, in the proportion of six large to four small heads, varies from 5*l.* to 7*l.*; but in times of scarcity the price has been as high as 22*l.* the pack. In abundant years the pack has been sold as low as 3*l.*

Cloth was formerly teazled by hand; for which purpose a number of the heads were fixed in a small wooden frame, having cross handles eight or ten inches long, forming an instrument not unlike a curry-comb. The cloth to be teazled was hung upon two horizontal rails fastened to the ceiling. It was first damped, and then the men worked three times

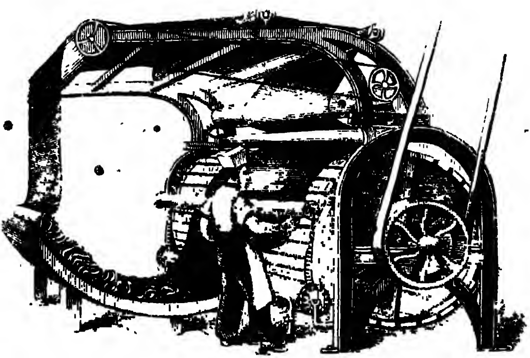
over its surface, first in the direction of the warp, and then in that of the weft, so as to raise the loose fibres from the felt, and to prepare it for shearing. When the heads became choked up with wool, they were cleared out by children, with small steel combs; but when the moisture had softened the points, it was necessary to dry the heads.

The high price of teazles, and the large number required in the manufacture (from two to three thousand being used on a piece of cloth forty yards long), have led to attempts to supersede the teazle by the introduction of wire brushes, or metallic teazle-cards, but they do but rudely imitate the action of the natural teazle, in which each head is composed of a great number of flowers separated from each other by long scales, at the end of which is a fine hook, the part so valuable to the manufacturer. These hooks are strong enough to overcome a slight impediment, but are sufficiently yielding to give way and break when they become fixed in a knot which they cannot disentangle. Metallic teazle-cards, on the contrary, instead of yielding, tear out the fibres, and injure the surface of the cloth.

The great improvement in teazling has been by the introduction of machinery. In the *gig-mill*, as it is called, the teazles are arranged in long frames attached to a hollow drum, or cylinder, and the cloth being guided by a number of rollers, is moved in a direction contrary to that of the cylinder, by which means its surface is exposed to the operation of the teazles. By the rapid revolution of the cylinder, and the slower motion of the cloth in a contrary direction, the loose fibres of the wool are brought to the surface. The long frames can be easily removed from the cylinder, and when the teazles become clogged with wool, they are removed and cleaned.

There are various forms of gig-mill, but the only

essential difference between them consists in the method of arranging the rollers, so as to bring a



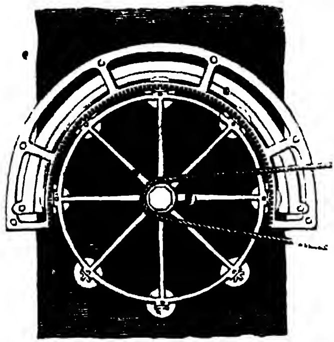
GIG-MILL FOR TEAZLING CLOTH

greater or less extent of surface of the cloth in contact with the cylinder.

SHEARING.

As the filaments drawn forth by teazling are of very unequal lengths, they must be shorn to make them level, and this must be done with different degrees of closeness, according to the quality of the stuff, and the appearance it is desired to have. Like most of the other operations of manufactures, this was formerly done by hand,—a large pair of shears being employed for the purpose, requiring considerable dexterity on the part of the workmen. The first improvement was to work these shears by machinery — a circumstance which led to serious riots in the West of England at the commencement of the present century. The folly of these disturbances it is not necessary to point out. Machinery was successful, and continued to be improved in various ways. One ingenious contrivance consists

of a fixed semicircular rack, within or behind which is a cutting edge, called a *ledger-blade*; and a large revolving wheel, armed with eight small cutting discs, which, being in contact with the ledger-blade, form, when in motion, a series of delicate cutting shears. Each cutting disc has a toothed pinion working in the semicircular rack, which, as the large wheel revolves, gives to the cutting discs an independent rotatory motion in addition to their revolution with the large wheel. In the diagram the cloth is

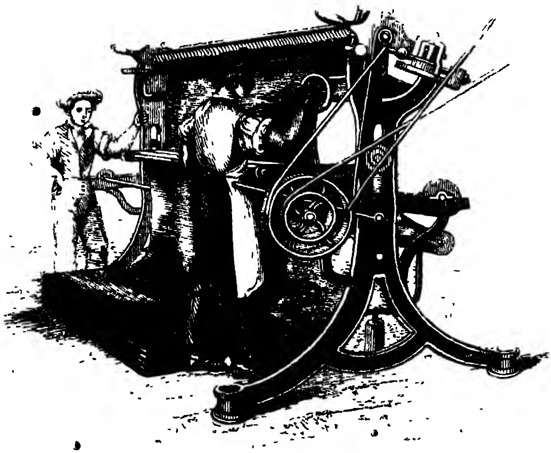


represented by the shaded part over which the machine travels; or the machine may be stationary while the cloth is moved beneath it.

The other machine in use consists of an iron cylinder, round which is a spiral cutting blade. The cylinder being made to revolve with great rapidity, the blade cuts the pile of the cloth immediately in contact beneath it, the cloth being stretched and guided by rollers. A machine of this kind is called a *perpetual*.

A single operation of raising and shearing is not sufficient to give its beautiful surface to superfine cloth. The cloth is therefore teazled a second time, deeper than the first; that is, the cloth is made to press with greater force against the teazles than in the first raising; it is then sheared a second time. By

alternately repeating these processes as often as may be required, the cloth at length assumes the appearance desired. In the West of England the first raising is called *roughing*, in which process the cloth



BROAD-PERPETUAL, FOR SHEARING

is worked with the teazles both ways. After being sheared it is teazled in one direction only, which is called *mozing*. It is then cut and teazled several times.

Both teazling and shearing are delicate operations: if badly done the cloth is weakened, and otherwise injured; but if well done, not only is the appearance of the fabric improved, but it acquires strength and durability; for the pile or nap is a species of fur which protects the cloth from friction and moisture.

ROLLER-BOILING.

Within the last few years a process has been introduced which greatly improves the lustre of the surface of the cloth, and prevents it from becoming spotted by rain. This process consists in winding

the cloth tightly upon a roller, and immersing it in water heated to 170° or 180° for twenty-four hours, after which it is once more stretched on the tenters and dried. This process is called *roller-boiling* or *patenting*. But as the long-continued action of hot water was found in some cases to weaken the fibre of the wool, and to change some colours, it is now customary to alternate the process with cold and hot water. For this purpose, the cloth is wound upon a drum, which rests upon a horizontal axis, half in and half out of a tank of cold water. Steam is admitted into the trough until the water is raised to the temperature of 170°. In the mean time a slow rotatory motion is given to the drum, the cloth becomes uniformly heated throughout, and by being passed in succession through the hot water and the cold air for the space of eight hours, the cloth gets a smooth soft face, and the texture is not injured. The hot water is then withdrawn, and its place supplied by cold water, in which the cloth is turned for the space of twenty-four hours, which will perfectly fix the lustre which the hot water has imparted to the face of the cloth, and leave the pile or nap in a soft silky state. This improvement is said to have been invented by Mr. Wilkins, of Tiverton, and perfected by Mr. Hirst, of Leeds.

BRUSHING, &c

When the cloth is dry it is removed to the brushing-machine; which is a series of brushes affixed to a cylinder. In passing through this machine, the cloth is slightly damped by being exposed to steam which escapes in minute jets from a copper box extending the whole length of the brushing-machine. For the purpose of brushing, a number of pieces are stitched together at the ends so as to form an endless web.

The cloth is once more carefully examined before a strong light, and is *picked*, *fine-drawn*, and *marked*. The picking (which is similar in its object to burling)

is to remove all blemishes which may appear on the surface, and to cover over with the point of a pen, dipped in ink or dye-stuff, any spots which may have escaped the action of the dye. Fine-drawing is to close any minute hole or break in the fabric, by introducing, by means of a needle, sound yarns in place of defective ones; and the marking is the working in, with white or yellow silk, a word or mark indicating the quality and number of the piece, such as, *Saxony, extra superfine*, and so on.

PRESSING.

The pile being once more brushed, the cloth is regularly folded and subjected to hydraulic pressure. Between each fold is placed a polished pressing-board to prevent the surfaces from coming in contact; and between each piece of cloth (many pieces being pressed at the same time) iron plates are inserted. If the cloth is to be hot-pressed, three hot iron plates are inserted between the folds at the end of every twenty yards. Thin sheets of iron, not heated, are also inserted above and below the hot plates for the purpose of moderating the heat. The folded pieces are piled up in the press, and subjected to very severe pressure, till the plates are cold. The cloth is then taken out and folded again, so that the creases of former folds may come opposite the flat faces of the pressing-boards, and be removed at the second pressure.

Hot-pressing gives a satiny lustre and smoothness to the face of the cloth, which, however, is apt to become spotted and disfigured by rain, an effect which is not produced on cloth which has been *patented*. Therefore, in finishing superfine cloths, a very slight pressure is given to them, and the iron plates are moderately warmed.

The cloth is lastly made up for the market in *pieces* or *bales*, and into *ends* or *half-pieces*.

STATISTICS OF THE WOOLLEN TRADE.

THE methods of carrying on the woollen trade differ in some respects in different counties, but they may all, perhaps, be referred to two systems, namely, the *factory system* and the *domestic system*. In the former, the master clothier procures foreign wool from the importer, and wool of home growth from the wool-stapler, and works it up into cloth in a large factory, employing for the purpose a number of operatives, consisting of men, women, and children, who have no property except their labour in the material upon which they are employed.

In the domestic system, the one originally adopted in this country, the manufacture is conducted by small masters, each of whom farms a few acres of land. The master, his wife, and children, occupy themselves alternately with the manufacture of woollen cloth, and the cultivation of their land. These domestic clothiers formerly made the wool into undressed cloth at their own houses; but of late years *public mills* have been established for the purpose in the clothing villages: these mills are a joint stock undertaking, each clothier subscribing 50*l.* or 100*l.* In the early part of the present century, when the factory system, with its powerful and extensive mechanical resources, was becoming generally adopted in the woollen manufacture, the domestic clothiers were under considerable alarm for the safety of their trade. A Parliamentary Committee, appointed to inquire into their case, reported that "the two systems, instead of rivalling, are mutual aids to each other; each supplying the other's defects, and promoting the other's prosperity." Experience seems to have confirmed this conclusion: the number of small manufacturers, and the quantity of cloth produced

by them, have both increased; but as the number of factories, and the quantity of cloth made in them, have increased still more rapidly, the small manufacturers now form a less proportion of the trade.

With respect to the value of the woollen trade, and the number of persons employed, Mr. M'Culloch has formed the following estimate. There are about 150,000,000 lbs. of wool worked up yearly: the value of this is taken at about 7,500,000*l.*: the value of the manufactured goods being taken at three times that of the raw wool, gives an annual amount of 22,500,000*l.* This valuation is made up in the following manner:—

Raw material	£7,500,000
Oil, soap, dye-stuffs, &c.	1,600,000
Interest, profit, &c.	4,650,000
Wages	8,750,000
	£22,500,000

Dividing the amount of wages at the average rate of 26*l.* a-year to each operative, gives 336,538; which Mr. M'Culloch thinks may be taken as the number of persons employed in the woollen manufacture of this country.

Mr. Chapman, one of the Assistant Hand-loom Commissioners, by taking the number of persons *supported* by the woollen manufacture, arrives at a larger result. He estimates that, in 1831, the number of *families* engaged in the manufacture were as follows:—

In the West Riding of Yorkshire . . .	85,096
In the West of England	20,851
In Norfolk and Kendal	17,570
In the Hosiery district	20,464
In other places	20,000
	163,981

Then taking the average number of persons in a family at 5⅓, he arrives at the aggregate of 874,565 persons directly supported by the woollen manufac-

ture. He also supposes that, by the year 1841, this number must have increased to 226,298 families, or 1,218,424 individuals. He supposes that the average earnings of each family is 17*s.* 6*d.* per week, which amounts to 10,296,559*l.*; and allowing for the increase in the other items since Mr. M'Culloch's estimate was made, he states the annual value of the woollen manufacture in this country thus:—

Value of wool employed . . .	£10,000,000
Oil, dye-stuffs, soap, &c. . . .	1,500,000
Wages	10,296,559
Wear and tear, profit . . .	4,359,311
	£26,155,870

The quantities and declared value of British woollen and worsted manufactures exported in 1820, 1830, 1840, and 1845, were as follows:—

	1820.	1830.	1840.	1845.	
Cloths of all sorts .	288,228	388,269	215,746	307,791	Pieces
Napped coatings	59,641	22,377	16,094	4,773	Pieces.
Kerseymeres . .	78,911	31,714	27,122	24,673	Pieces.
Baizes	37,183	49,161	36,044	23,583	Pieces
Stuffs . . .	828,824	1,252,512	1,718,617	2,212,906	Pieces
Flannels	2,567,196	1,613,099	1,613,177	2,465,311	Yards.
Blanketing . .	1,288,109	2,176,391	2,162,653	2,179,178	Yards.
Carpeting . .	525,990	672,869	758,639	1,006,970	Yards.
Woollens mixed with cottons . .	407,716	1,099,518	3,628,874	23,831,017	Yards.
Worsted hosiery .	59,390	111,116	96,946	171,061	Dozen p
Sundries . . .	£39,313	£54,038	£161,034	£178,995	Value.
Declared value	£5,597,758	£4,728,666	£5,327,853	£7,693,118	

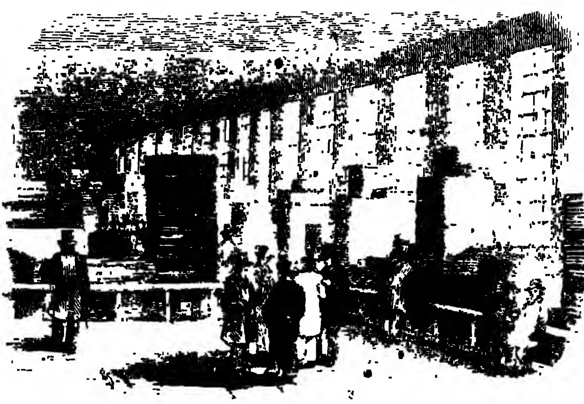
This table does not include the exports of British sheep and lambs' wool, and woollen and worsted yarns, during the same period. They were as follows:—

	1820.	1830.	1840.	1845.
Wool . . .	35,242	2,951,000	4,810,387	9,059,448 lbs.
Spun-yarn .	11,081	1,108,023	3,796,644	9,405,928 lbs.

In the Parliamentary documents for 1845, the exports of British woollen manufactures (exclusive of wool and yarn) are entered for forty-five different

parts of the world; by which it appears, that our best customer is the United States of America, to which woollen manufactured articles were sent in that year to the amount of 1,763,174*l.*: the Hanseatic Towns are entered at 981,504*l.*: the British North American colonies at 671,998*l.*; China at 539,218*l.*; Holland at 460,122*l.*

Halls, for the sale of cloth, are established at Leeds, Halifax, Huddersfield, Bradford, and other places. A notice of the Coloured-cloth Hall at Leeds, visited by the writer, will probably be a sufficient description of the management of these buildings. There are two cloth-halls at Leeds: the



INTERIOR OF CLOTH HALL, LEEDS

Coloured-cloth Hall, built in 1758, and the White-cloth Hall, built in 1775. The cloth-market was formerly held in an open street. The Coloured-cloth Hall is a plain building, occupying three sides of a large square, divided into eight compartments, which are called streets: these are, King-street, Queen-street, 'Change-alley, Mary's-lane, Prince of

Wales's-street, Cheapside, Commercial-street, Union-street, and New-street. Each street contains two rows of stands facing each other: each stand projects from the wall 11 or 12 feet; but it measures only 22 inches in front: it is inscribed with the name of the clothier to whom it belongs. No one can occupy a stand unless he has served a regular apprenticeship to the clothing business. Each stand, which is the absolute freehold property of the holder, cost originally about 3*l.*; and the value has been as much as eight or ten times that amount; but, since the extension of the factory system, a good deal of cloth produced in the woollen district is sold without passing through the halls, which have, consequently, lost much of their importance, and the stands do not now exceed their original value. The markets for the sale of coloured cloths are held on Tuesdays and Saturdays; on which days only are the merchants permitted to make their purchases in the halls. The time of sale commences, by the ringing of a bell, at nine o'clock in summer, and half-an-hour later in the winter half of the year from October to March. At the end of an hour the bell is rung again, to warn the buyers and sellers that the market is about to close; and in another twenty minutes the bell is rung for the third time; after which, a fine of 5*s.* is imposed on every buyer. The White-cloth Hall, situated in another part of the city, is opened immediately afterwards, and is subject to similar regulations. The cloth is brought to the halls in the undressed state; the purchasers, who are the proprietors of what are called *finishing-shops*, conduct the various finishing processes described in the present treatise. The goods produced in the West of England, and in Norfolk, are not sold in cloth-halls, but at public fairs or markets, or to the agents sent round by the drapers.

In this notice of the woollen and worsted manufacture, it might be expected that some details should

be given of the modes of manufacture of the various descriptions of goods in which wool is employed; but it may be stated that such goods as blankets, flannels, baize, stuffs, merinos, mousseline-de-laines or wool muslins, bombazets, tammies, shalloons, says, moreens, calimancoes, camlets, lustrings, and a number of others, are produced by some of the means already described in the treatises on the Manufacture of Woollen and Worsted Yarns, and of Woven Goods. Many divisions and subdivisions of the manufacture differ more in their results than in the means by which those results are attained. The mixture of woollen with worsted yarns, or either of them with cotton or silk, together with various methods of dyeing and fancy weaving, leads to an almost endless variety of woven fabrics. Thus to give a few examples:—*Kerseymere* is a fulled twilled fabric; *Serges* are also twilled, but the warp is worsted and the weft woollen; *Blankets*, and many varieties of plain coarse cloth, are made of very soft yarn, afterwards worked up into a kind of pile by milling; *Bombazeen* is a mixture of worsted and silk, twilled; *Poplin* is a similar mixture produced by plain weaving; *Stuff* is entirely worsted; *Merino* is a fine woollen twill; *Saxonies* and *Orleans* are made of woollen mixed with cotton yarn: *Cashmere* ought properly to be made of the wool of the Cashmere goat; but most of the fabrics named *Cashmeres* are made of sheep's wool; *Challis* is produced from a silk warp and a woollen weft, and is usually printed; *Mousseline-de-laine* was, as its name implies, originally all wool; but it is now commonly mixed with cotton, and printed; *Norwich Crape* is comprised of wool and silk; *Crêpe-de-Lyon* of worsted and silk. The fabrics called *Waistcoatings* are exceedingly numerous.

The principal seats of the woollen manufacture * are the West Riding of Yorkshire, and the counties

* The writer's information on this subject is obtained chiefly from M'Culloch's "Statistical Account of the British Empire."

of Gloucester, Wilts, and Somerset. The manufacturing district of the West Riding of Yorkshire is, with the exception of that of Lancashire, by far the most important of any in the kingdom. It extends from north to south about forty, its mean breadth being about twenty miles, comprising an area of nearly eight hundred square miles, and including the important towns of Leeds, Bradford, Halifax, Huddersfield, and Wakefield. The greater part of the *cloth* produced in this district is in the neighbourhood of Leeds, Wakefield, Huddersfield, and Saddleworth,—Leeds being the grand mart for *coloured* (or *mixed cloths*, as they are called, being wholly made of dyed wool,) and *white broad cloths*. *Flannels* and *baizes* are manufactured in and near Halifax, and also cloth used by the army. The *blanket* and *flushing* line lies between Leeds and Huddersfield. *Worsted* spinning is extensively carried on at Bradford; *stuffs* are made in its vicinity, and also in Halifax and Leeds. *Narrow cloths* are made in and near Huddersfield. Saddleworth furnishes broad cloths and *kerseymeres*. Wakefield is celebrated for the skill of its cloth dyers. In the neighbourhood of Batley and Dewsbury are the *shoddy-mills* employed in manufacturing yarn from old woollen rags and refuse goods, of which considerable quantities are imported. A little new wool is usually intermixed with the old, and the cloth answers sufficiently well for padding and such purposes.

Rochdale, in Lancashire, though not considered as forming part of the woollen district, has extensive manufactures of baizes, flannels, kerseys, and broad cloths.

In the West of England, the extent of the woollen manufacture is greatest in Gloucestershire, especially in the district called the *Bottoms*, of which Stroud may be considered as the manufacturing centre, all the surrounding valleys exhibiting ranges of houses or villages occupied by persons engaged in this business, and the banks of the Frome being thickly

set with fulling-mills. Broad cloths of various sorts are made in this district, but chiefly superfine, of Saxon, Australian, and Spanish wool; and fine narrow fancy goods are also extensively produced.

Bradford, in Wiltshire, is the centre of what is perhaps the greatest fabric of superfine cloth in England. Woollen cloth of thin texture is made at Wilton, and cloths of various qualities, but all fine, are made at Warminster, Heytesbury, and Calne. In Somersetshire, the manufacture is carried on chiefly at Tiverton and at Taunton, the latter being as celebrated for its manufacture of second cloth as Frome is for superfine. West of England cloths are commonly divided into five classes, according to their thickness: the thickest is *double-milled superfine;* the finest and thickest cloths are for the Turkey trade; *ladies' cloths* are rather thicker than these; cloths manufactured for the East and West Indies, a degree thicker; the superfine being, in point of thickness, next to the double-milled superfine. The Western woollen manufacture also extends into parts of Dorsetshire; while baize and flannels are produced at Sturminster Newton.

The county of Norfolk was long the seat of the stuff or worsted manufacture; but during the present century it has declined, chiefly, it is said, for want of coal. The greater part of the yarn now made use of in the Norwich factories is made at Bradford, in Yorkshire. Worsted yarn is also produced largely in Leicestershire, and to some extent in Warwick and other places.

Exclusive of the leading fabrics already adverted to, an immense variety of woollen goods are manufactured in various places, only a few of which can be noticed here. Baize and flannel are made at Bury, in Lancashire; baize, coarse cloth, and blankets, at Chichester, in Sussex. Salisbury produces flannel in small quantity. Blankets are made at Dewsbury, Witney, Dulverton, &c.; but with respect to Witney

it is remarked, that since the introduction of machinery, the chief part of the blankets sold at its markets are made in Glamorganshire.

The manufacture of carpets, druggets, and woollen and worsted stockings, will be noticed in a separate treatise.

The woollen manufacture of Wales is principally situated in the counties of Montgomery, Merioneth, and Denbigh. Its products consist of webs, flannels (the most important article of Welsh manufactures), stockings, socks, wigs, and gloves. In many parts of Wales almost every small farmer makes webs, and few cottages are without a loom.

The woollen manufacture of Scotland is inconsiderable. Fine cloth is produced in various parts of Aberdeenshire, and in some other counties; but coarse cloth is the staple article of Scotch manufacture. Some of the woollen spinning mills and factories at and near Aberdeen are upon a large scale.

In Ireland the woollen manufacture is in a very depressed state, owing in great measure, to the unsettled state of the country.

With respect to the health of the operatives employed in woollen factories, a favourable opinion may be given. Mr. Thackrah states that slubbers and spinners are robust and healthy. Some of the other departments are less favourable; but on the whole, there does not appear to be anything in the manufacture itself which is prejudicial to health.

THE USEFUL ARTS

AND

MANUFACTURES OF GREAT BRITAIN.

THE MANUFACTURE OF HOSIERY.

HISTORICAL NOTICE OF KNITTING AND OF THE KNITTING FRAME.

In the manufacture of woven cloth a number of warp threads are extended parallel to each other, and the weft is thrown across so as to interlace with them. In knitting, whether by hand or by machine, a single thread is entwined so as to produce a tissue resembling cloth. Netting resembles knitting, inasmuch as a net is composed of a single thread; but a net is composed of distinct meshes, formed by tying the thread or cord into hard knots, at those points where it crosses upon itself; whereas in knitting, the thread is formed into a succession of loops, which run into each other, without being tied into knots. Thus one of the meshes of a net may be broken without injuring the others; but if the thread of a stocking be broken, a hole is produced which continually enlarges from the unlooping of the thread.

Knitting and netting are familiar occupations much more easy to learn than to describe in writing. Beckmann, who gives a pleasing list of the advantages of knitting, advises those who wish to learn the art to get some person to instruct them. "For," he says, "it is to be reckoned among the advantages of the

present age, that a readiness in knitting is required as a part of female education in all ranks;* and it may be easily acquired even by children, with the assistance of an expert and indulgent instructress. * * This occupation, which, with a little practice, becomes so easy that it may be called rather an amusement, does not interrupt discourse, distract the attention, or check the powers of the imagination. It forms a ready resource when a vacuity occurs in conversation, or when a circumstance takes place which ought to be heard or seen but not treated with too much seriousness: the prudent knitter then hears and sees what she does not wish to seem to hear or to see. Knitting does no injury either to the body or the mind. It occasions no prejudicial or disagreeable position, requires no straining of the eye-sight, and can be performed with as much convenience when standing or walking as when sitting. It may be interrupted without loss, and again resumed without trouble; and the whole apparatus for knitting, which is cheap, needs so little room, and is so light, that it can be kept and gracefully carried about in a basket, the beauty of which displays the expertness, or at any rate the taste of the fair artist. Knitting belongs to the few useful occupations of old persons, who have not lost the use of their hands." The learned author then goes on to recommend that servants, soldiers, shepherds, and the male children of the peasants who are unfit for hard labour, learn to knit, that they may earn something for themselves and their families.†
To this it may be added, that netting is a pleasant occupation for the leisure of the male sex.

Fishing and hunting nets are frequently mentioned in Scripture,‡ and the ancient Greeks and Romans appear to have made their nets much in the same manner as the moderns. Nor is the art of knitting

* Since Beckmann's time, *Crochet* and other kinds of fancy work have to a great extent superseded knitting.

† History of Inventions, vol. iv. ‡ Ezekiel xxvi. 14; xliv. 10.

nets of fine yarn, silk, or cotton, for the purpose of dress or ornament, a modern invention. Beckmann says,—"I remember to have seen in old churches retiform hangings, and on old dresses of ceremony borders or trimming of the same kind, which fashion seems alternately to have banished and recalled." In the middle ages the mantles of the clergy had often coverings of silk, made in the same manner as fishing nets.

The art of knitting stockings was a more ingenious and a later invention than netting. The Romans, and most of the ancient nations, had no particular clothing for the lower part of the body; but the people who inhabited northern countries had hose, or trowsers, which only a few centuries ago were converted into two articles of dress. The first stockings were of cloth, and were made by the tailors; their appearance of course being much more clumsy than our knit stockings, which, from their elastic nature, fit tightly to the leg, without impeding a person in walking.

In old Saxon figures a bandaged stocking is very common, resembling in appearance the Highland stocking. It was in common use among the shepherds and country people of France during the fifteenth and sixteenth centuries. This part of the dress was made of white linen and called *des lingettes*, a name also applied to a part of the ancient costume of the women of the Pays de Caux, that covered the arm. The contadini of the Apennines at the present day wear a kind of stocking bandaged all the way up.*

The art of knitting stockings is supposed by Savary to have been invented in Scotland in the sixteenth century, from the circumstance that when the French stocking knitters, in 1527, became numerous enough to form a guild, they chose for their patron St. Fiacre, a native of Scotland; and there is also a tradition that the first knit stockings seen in France were from

* Archæologia, vol. xxiv.

Scotland. Other writers support the opinion founded on the following passage in Howel's History of the World, (which was printed in 1680-85,) that the art of knitting stockings came from Spain. Speaking of the costliness of silk in ancient times, the author goes on to say :—" Silk is now grown nigh as common as wool, and become the cloathing of those in the kitchen as well as the court: we wore it only on our backs, but of late years on our legs and feet, and tread on that which formerly was of the same value with gold itself. Yet that magnificent and expensive prince Henry VIII. wore ordinarily cloth-hose, except there came from Spain, by great chance, a pair of silk stockings. King Edward, his son, was presented with a pair of long Spanish silk stockings by Sir Thomas Gresham, his merchant, and the present was taken much notice of. Queen Elizabeth, in the third year of her reign, was presented by Mrs. Montague, her silk woman, with a pair of black knit silk stockings, and thenceforth she never wore cloth any more."

This information is confirmed by Stow, who also states that the Earl of Pembroke was the first nobleman who wore worsted knit stockings. In 1564, William Rider, an apprentice of Master Thomas Burdet, having seen in the shop of an Italian merchant a pair of knit worsted stockings from Mantua, borrowed them, and made a pair exactly like them, and these are said to have been the first stockings of woollen yarn knit in England.

Very soon after the art of knitting stockings was known in England, it was adopted as a domestic employment. When Queen Elizabeth visited Norwich about the year 1579, several female children appeared before her, some of whom were spinning worsted yarn, and others knitting hose of the same material.

Not many years after the introduction of knitting into England, an attempt was made to expedite the work by machinery. The history of the stocking

frame is somewhat obscure, but most writers admit the truth of the inscription to a picture contained in the Stocking Weavers' Hall, in Red-cross-street, London, representing a man pointing to an iron stocking frame and addressing a woman who is knitting with needles by hand. The inscription is as follows:—"In the year 1589 the ingenious William Lee, Master of Arts, of St. John's College, Cambridge, devised this profitable art for stockings, (but being despised, went to France,) yet of iron to himself, but to us and others of gold; in memory of whom this is here painted."

This William Lee (or Lea as it is sometimes spelled) was a native of Woodborough, in Nottinghamshire. According to one account he was expelled from the University for marrying contrary to the statutes, and having no other means of support than his wife's earnings as a stocking knitter, he contrived his frame for the purpose of performing the work quicker. But, according to a tradition in the neighbourhood of Lee's birth-place, he is said to have first learned the art of knitting from watching the dexterous movements of the hand of a lady whom he was courting, and then conceived the idea of making artificial fingers for knitting many loops at once. With the natural ardour of an inventor, he devoted his days and nights to the accomplishment of his scheme, and having succeeded, he instructed his brother James in the use of the frame, and proceeded to make a profitable application of his invention, first at Calverton, a village near Nottingham, and shortly after in London. In the latter place he succeeded in obtaining the notice of Queen Elizabeth, who, accompanied by her kinsman, Lord Hunsdon,* and his son, is said to have actually visited him in order to see him work at his frame. The queen expressed her

* According to Mr. Felkin, Lord Hunsdon entered into a kind of partnership with Lee, and thus one of the Tudor family became the first stocking-maker's apprentice.

disappointment that he was making woollen instead of silk stockings, and refused to make him either a grant of money or to give him a patent of monopoly. Her answer to Lord Hunsdon, who interceded in his favour, is said to have been :—" My Lord, I have too much love to my poor people, who obtain their bread by the employment of knitting, to give my money to forward an invention which will tend to their ruin, by depriving them of employment, and thus make them beggars. Had Mr. Lee made a machine that would have made silk stockings, I should, I think, have been somewhat justified in granting him a patent for that monopoly, which would have affected only a small number of my subjects; but to enjoy the exclusive privilege of making stockings for the whole of my subjects, is too important to grant to any individual."

Hoping to obtain a patent for his machine, if he adapted it to the making of silk stockings, Lee set to work to produce the desired result, and about the years 1596-7 succeeded in making plain silk stockings from a twenty-gauge silk frame. He erected nine frames, which were worked by apprentices consisting chiefly of his relatives, who esteemed it so high an honour to belong to the new craft, that they wore their working needles with ornamented silver shafts, suspended from a silver chain at their breasts. The death of the queen, however, again blighted the hopes of Lee, and some time afterwards, when Sully came to London, as ambassador for Henry IV. of France, on a special mission, he made Lee very splendid offers to induce him to remove himself and his machinery to France. The disturbed state of that country led him at first to decline the offer, but some years afterwards, finding that the king, James I, was even more unfavourably disposed to his invention than Elizabeth had been, he removed the whole of his machinery and workmen to Rouen, in Normandy. Having established his frames in that city, he went to Paris, and had the honour of

a personal introduction to Henry IV. at the hands of the Duke of Sully. Every thing seemed to promise success; but the troubles consequent on the murder of the king destroyed Lee's prospects; he was proscribed as a Protestant, and was obliged to seek concealment in Paris, where he died in poverty and distress. Lee's brother, and all the workmen except two, found their way back to England. The two who remained were allowed to retain one frame; the other frames were brought to England, and one of them appears to have been sold to a person named Mead, in the city of London.

The attempt which had been made by Sully to plant the infant manufacture in France, was also made by the ambassador from Venice in favour of that city, then the most commercial and manufacturing in the world. He paid Mead the sum of 500*l.* for the purchase of his frame, and his personal superintendence of it at Venice. But as he could not make his own needles, nor repair his frame, his work was soon brought to a stand. The Venetians also failed in their endeavours to copy the machine; and as Mead, at the expiration of his engagement, insisted on returning to London, the whole scheme of Venetian frame-work knitting was abandoned. This was about the year 1621.

After the return of Lee's work-people to London, they did not remain idle. Through their means the number of frames and frame-work knitters increased rapidly, so that early in the seventeenth century the frame-work knitters resident in London, which was then the principal seat of the manufacture, formed themselves into a company, and petitioned Cromwell to constitute them a body corporate. In their memorial they stated that their trade was "properly styled frame-work knitting, because it is direct and absolute knit-work in the stitches thereof, nothing different therein from the common way of knitting, (not much more anciently for public use practised in this nation

than this,) but only in the numbers of needles, at an instant working in this more than in the other by an hundred for one, set in an engine or frame composed of above two thousand pieces of smith's, joiner's, and turner's work, after so artificial and exact a manner, that by the judgment of all beholders it far excels in the ingenuity, curiosity, and subtilty of the invention and contexture, all other frames or instruments of manufacture in use in any known part of the world."

The Protector does not appear to have paid any attention to this petition; but immediately after the Restoration it was renewed, and at length, in 1663, the petitioners obtained a charter which was to come into operation in the following year.

This charter gave a great impetus to the trade in London and its neighbourhood; the prices of admission to the Company were low, and the number of applicants large. The master, wardens, clerks, assistants and deputies were the only parties who were electors; and the assistants, at the end of forty years, were composed partly of frame-work knitters, and partly of persons who had bought their livery for the sake of the vote. The Company had a large income, arising from the fees for registering apprentices, enrolling freemen of their Company, and levying of fines; which income was further increased by the premiums for the sale of freedoms and of the livery. As the Company was restricted from holding more than 100*l.* a year, they managed to get rid of the large surplus in various ways. The people in those days were very fond of gorgeous processions, and the chartered trade companies made a grand display at the installation of each Lord Mayor of London, on the Ninth of November, when they proceeded through the streets of the city to Blackfriars-bridge, whence they embarked on the water to Westminster-hall, where the Lord Mayor took his oath of office before the Barons of the Exchequer,—a custom still extant. The Frame-work knitter's Company soon emulated

the pomp of the other Companies. "'A gilt barge was built, rowed by twenty watermen in splendid liveries, accompanied by a numerous band of musicians, and adorned with magnificent flags, bearing the arms of the Company emblazoned, which are a representation of the stocking frame without the wood work, having the web on the frame divided at the heel. The supporters are a clergyman, dressed in the Cambridge habit, and a woman habited in the costume of 1665. The motto is 'Speed, Strength, and Truth united.' A new hall was built in Red-cross-street wherein to transact the concerns of the Company, and they scarcely ever met upon business, but they had a sumptuous feast prepared. To support this pageantry and extravagance considerable sums of money became necessary, and the fees for enrolment of apprentices and taking up the freedom were raised to a sum which was considered exorbitant." The trade had by this time extended to Leicester, Nottingham, and Derby. The Nottingham deputies held their Court monthly, and being urged by the Company in London, acted with considerable rigour in their office, and endeavoured to prevent the extension of the trade. Two assistants were sent from London quarterly, for the purpose of enforcing their authority, and collecting fees and fines.

As it was an object with the Company to retain the seat of the manufacture in London, the Company became an object of dislike to other towns, and attempts were made to set its authority at defiance. The bye-laws of the Company had limited the number of apprentices to the rate of three for one journeyman. Many persons had infringed this regulation: some removed their frames to Nottingham, among whom one named Fellowes was stated to have no less than forty-nine apprentices; others took an almost unlimited number of parish apprentices, with whom a premium of £5 was given. The London Company endeavoured to check this system by legal proceed-

ings, in which, after a very long contest, they were defeated. The consequences were disastrous to the journeymen, whose place was almost entirely occupied by the apprentices; the poverty of the journeymen soon became proverbial, and "as poor as a stockinger" was heard as early as 1740.

In 1745 the Company made a new set of bye-laws, and endeavoured to enforce them; but the trade at Nottingham refused to submit, petitioning Parliament against them as being contrary to the general liberty of the subject, and injurious to the trade. In 1753, a Committee of the House of Commons reported that the statements of the petitioners had been proved, and thus the authority of the Company was annihilated.

It will not be necessary to trace the history of the stocking trade further, except to enumerate the number of frames existing at different periods, which will give some idea of the extent to which production has increased. It must, however, be borne in mind, that in recent times the frames are broader than those formerly in use, and are moved with increased speed; circumstances which produce a larger proportional quantity of work.

In the year 1669 there were 660 frames in the trade, of which number 490 were in London, three-fifths of the whole being employed in the manufacture of silk goods. In 1710 a hundred frames were destroyed in London on account of disputes about wages, and in 1714 there were 2,500 frames in London, 600 in Leicester, 400 in Nottingham, and about 8,000 throughout all England. From this time the trade began to leave London, and in 1753, when the total number of frames in England was 14,000, the number in London was only 1,000, while the number in Nottingham had risen to 1,500, and in Leicester to 1,000. By this time the manufacture of thread, as well as India and home-spun cotton, had extended over the counties of Nottingham and

Derby. The first pair of cotton stockings made in England was at Nottingham, in 1730.

In 1782 the total number of frames amounted to 20,000, in 1812 to 29,590*, and in 1832 to 33,000.

In 1844 the frames in employ in the United Kingdom were estimated at 42,652, and those unemployed at 5,830, making a total of 48,482.

About the year 1756, Jedediah Strutt invented a machine for making ribbed stockings, and in conjunction with his brother-in-law Mr. Woollatt, a hosier of Derby, took out a patent for the same. This improvement led to several others, such as open-work mittens, and fancy articles in the stocking stitch. But with the exception of this addition, the stocking frame seems to have reached a nearly perfect state about the year 1714. Lee's frame has the singular merit of having been the first invention successfully used for superseding hand labour, by the use of a machine, in making clothing. It is an honourable proof of the constructive genius of Lee, considering the early date of the invention, when so few machines were in existence to afford him aid, and when the numerous resources of modern mechanical science were unknown. Additions to the frame were made by Aston, a miller, of Thoroton, in 1620; by Needham, in 1670, and also by Hardy, in 1714, both London frame-work knitters; since which it has acquired no new powers, but continues to be worked by hand, not because it is incapable of the application of steam power, but on account of the abundance, and consequent cheapness of hand labour; the supply of frame-work knitters for many years past having greatly exceeded the demand for them.

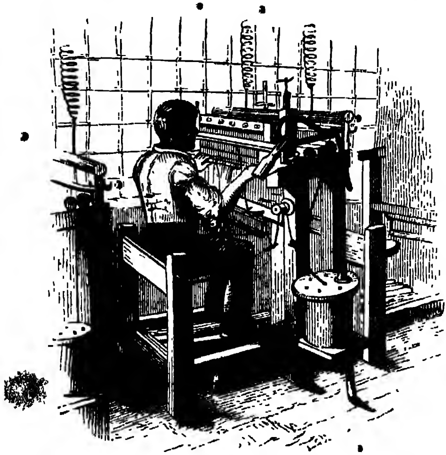
FRAME-WORK KNITTING.

Frame-work knitting is, for the most part, a domestic branch of industry, and has no connexion

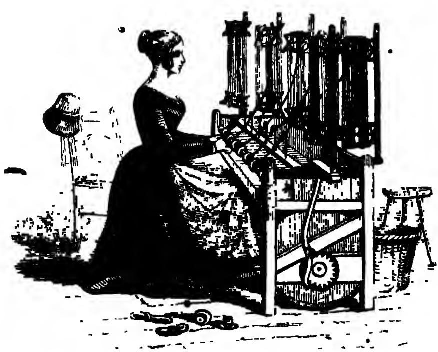
with the factory system. The stocking weavers of Nottingham and its neighbourhood live, for the most part, in their own houses or rooms, and are furnished with frames, either by the wholesale dealers or hosiers, who pay after a certain rate for work performed; or by a class of middlemen, called master stocking-makers, who charge a certain sum for the use of their frames, without reference to the quantity of work performed. These frames are protected by law from distress for rent and from execution for debt; the master stocking-makers collect the work, pay the operatives, and transfer it to the wholesale dealers.

In some instances, however, there is an approach to the factory system; when one master stocking-maker is the owner of several frames, which he collects under one roof, and engages operatives to work at them, paying for the amount of work produced. Such is the case at the establishment at Nottingham visited by the writer. Here the looms are collected in the upper story of three houses, all the rooms of which communicate with each other, but are shut off from two of the houses of which they form a part, communication being made to them by the central house only. The rooms are lighted by a range of windows both front and back, alongside of which the frames are situated, from seven to nine in each room, the central space being unoccupied. One room is devoted to winding and preparing the silk thread, seaming the hose, &c. At this establishment silk hose is produced, which being the best description of work fetches the best prices. A natural consequence of this is an air of comfort about the place, showing that the people have time to keep their workshop tidy. Very different is the appearance of the rooms where cotton hose is made. For this the lowest rates of remuneration are paid; and we see a number of large heavy looms crowded into one dark dingy room, where the operatives, incessantly labouring fourteen

or fifteen hours every day, are scarcely able to earn a subsistence for themselves and their families.



HOSIER AT WORK.



The stocking-frame is an exceedingly complicated machine, the number of moving parts being very great, and collected together in a very small compass. In the construction of a frame the nicest workman-

ship is required; any little derangement, such as the bending of a needle, rendering the whole machine unserviceable. The separate parts of the machine are made by the frame-smith, and are then put together by the *setters-up*, a class of workmen whose business it is to put in order any frame which by accident or ill-usage has been deranged; but in all ordinary cases the stocking-maker has to keep his frame in working order. The setters-up have about the same relation to the frame-smiths that the watch-makers have to the makers of the works, or the tuners of the pianoforte to the makers of that instrument. Although liable to derangement, the frames are very durable, many of those now in use having been made in the reign of Queen Anne.

It is scarcely possible, by a written description, to convey a complete idea of the stocking frame; but by attending to a few of the most important working parts, the reader will be able to form an idea of the principle of this complex machine.*

In hand-knitting, two straight wires, called *knitting needles*, are used, and the operation consists in forming a series of loops upon one needle and inserting them within another series contained upon the other needle. This is effected by four movements:—1. Pushing the right-hand needle through the first loop of the left-hand needle. 2. Turning the thread once round the right-hand needle, to form a new loop. 3. Drawing the new loop through one of the former series. 4. Pushing the old loop off the left-hand needle. When one row of loops is completed the needles are made to change hands, and a new course is commenced.

In knitting by the stocking frame a number of needles is employed which varies according to the fineness of the work, from fifteen to forty being contained in an inch; the largest number being used

* The most elaborate and by far the best description which the writer has seen of the stocking frame, is that contained in Rees's Cyclopædia, to which he desires to express his obligations.

for the finest stockings. They are made of iron wire, of the shape represented in the figure, with a

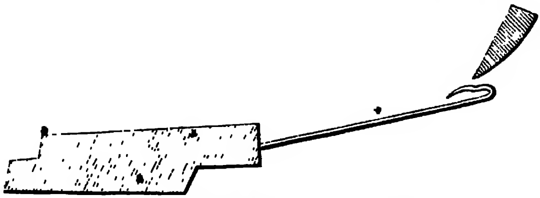


FIG. 1. NEEDLE OF THE ACTUAL SIZE.

hook or barb at the end, and the sharp ends very fine and delicate. There is a small cavity or groove punched or sunk in the stem of each needle immediately beneath the barb, of sufficient depth to receive the point when pressure is applied upon the hook to bend the barb down. The barb then becomes a closed eye, and if a thread is looped over the stem of the needle and drawn forwards while the barb is thus closed, it will pass over the barb of the needle and come off at the end of it: but if the thread is drawn forwards while the barb is open, it will be caught under the hook, and thus be detained. The principal action of the machine depends upon this circumstance. The depression of the barbs of the needles is produced by the edge of a presser-bar, which is extended horizontally over the whole length of the needles, and is acted upon by pressing the foot upon the middle one of the three treadles of the machine.

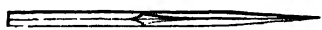


Fig. 2.

The needles are fitted into the frame by being first cast into tin sockets, called *leads*. The form of the needle, when complete and fitted to its place in the frame, is shown in figure 1, which also shows a section of the presser-bar. In front of the needle-bar is a small piece of iron, called the verge, to regulate the position of the needles. When placed upon the bar, resting against the verge, another plate of iron, generally lined with soft leather, is screwed

down upon the sockets or leads, in order to keep them all fast. When the presser-bar is forced down upon the barb, the needle is shut, and when the presser-bar rises, the barb rises or opens by its own elasticity.

Figure 3 represents a single thread (R) formed

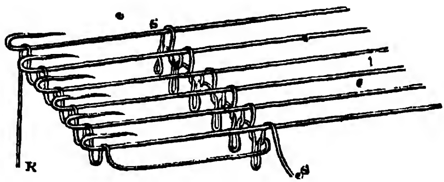


Figure 3.

into a number of loops by arranging it over an equal number of parallel needles (1); these are retained or kept in the form of loops by being drawn or looped through similar loops formed by the thread of the preceding course of the work (S S). This is the common stocking-stitch used for plain hosiery; and the whole operation of the common stocking frame consists in the formation of a series of loops, and then drawing them successively through a series of other loops, as long as the work is continued. There are many different kinds of stocking-stitch used for ornamental hosiery, each requiring a different frame or machine to produce it.

The next part of the machine requiring description is that for forming the loops. This consists of two parts, the *jack-sinkers* and the *lead-sinkers*. The jack-sinkers consist of a succession of horizontal levers or jacks (*h*) moving upon a common centre; each jack is furnished with a joint, from which hangs a very thin plate of polished iron called a *sinker*. One of these jacks and sinkers is allotted to every alternate needle in the frame, the sinkers hanging down between them. The other ends of the jacks are tapered to a point; and when the jacks are in their horizontal position they are secured by small

iron springs (*k*), each having a notch to receive the point of the jack.

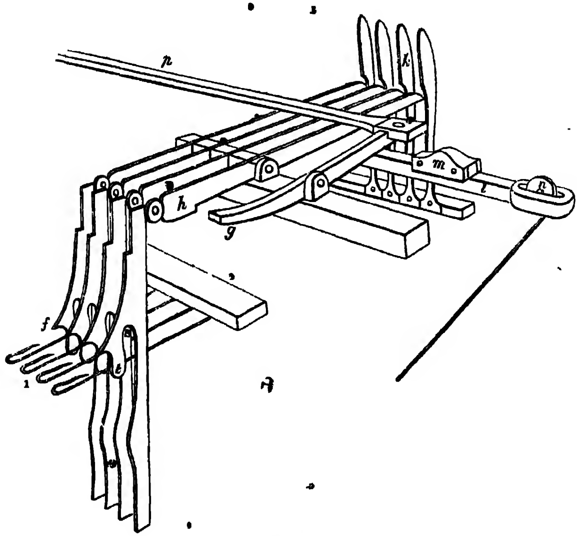


Figure 4.

The *lead-sinkers* resemble the jack-sinkers, but are differently attached; for while the jack-sinkers admit of being raised or lowered separately, the lead-sinkers are all fixed to one bar, called the *sinker-bar*, and must be raised or lowered all together. The lead-sinkers are placed alternately between the jack-sinkers; hence it follows, that between every two sinkers throughout is one needle.

The jack-sinkers being elevated so as to bring their *nips* (*f*) above the level of the needle, the thread is loosely thrown under these nips. Now it is obvious that on lowering the jacks a series of loops will be formed (see figure 3); but if the jacks were all lowered at once there would be danger of destroying the thread, an accident which is avoided by a very ingenious contrivance. A straight iron bar (*l*, figure 4), called the *slur-bar*, is extended beneath all

the jacks, and upon this a piece of metal (m), called the *slur*, travels with rollers; motion is given to it by a cord attached to each side of it, passing over a pulley (n), and connected, by means of a wheel, with the two outer treadles of the frame. By this means, the slur is made to travel backwards and forwards, thus lowering only one jack-sinker at a time, and depressing one loop of thread between every pair of needles. The loops thus formed are of double the depth required; in order, therefore, to bring them to the proper size, and to throw a loop between every two needles in

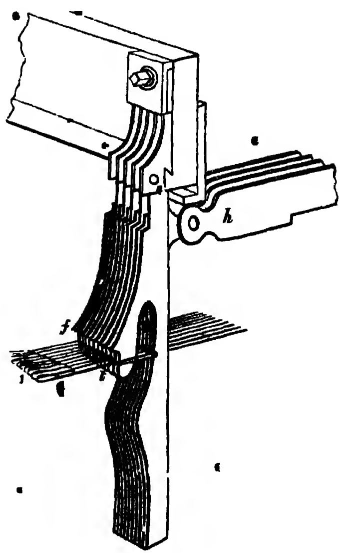


Figure 5

the frame, the workman next depresses the lead-sinkers all at once, and their nips ($f\,f$) carry down the thread between the remaining needles in loops. While this is being done, the jack-sinkers are made to rise up as much as the lead-sinkers are depressed; thus making all the loops throughout of the same size, and forming a loop between every two needles. This row of loops is next driven back upon the needles, (to S S Fig. 3,) so as to come below the arch or opening of the sinkers, (S S Fig. 4 and 5.) Here the loops are entirely removed from the action of the sinkers, and the workman proceeds to form a new row in front of the former, by a repetition of the process already described. This second row of loops is then brought forward, so as to be under the barbs or hooks of the needles. The presser-bar is next made to close

the barbs with the thread within them. The first formed loops are now brought forward from under the arch, upon the closed needles, and are made to pass over the ends of the needles, and the new-formed loops within them. By this means the loops of what was the upper or last course of the finished work become secured, and the loops under the barbs now become the upper course, and are preserved from unravelling by the needles, one of which passes through each loop; and these loops will not be drawn off from the needles until there is another row of loops prepared and ready to be drawn through them.

This description of working the courses of loops within each other will perhaps be more intelligible if we follow the workman in another course. Preparatory to this, the loops of the last course, and by which the work is suspended from the needles, must be pushed back upon the stems of the needles, so as to come into the arched or open part of the sinkers (S S); another row of loops is then formed and brought under the barbs; the barbs are then closed, and the row of loops under the arch is brought forward over the barbs, and over the ends of the needles, whereby the loops under the barbs are drawn through the loops which pass over the barbs, and thus, by a sort of circular motion, a web is formed which hangs down from the needles. When the piece is of considerable length it is wound upon a roller contained in an iron frame, the weight of which is sufficient to keep the web properly stretched.

Let us now briefly recapitulate the various movements of the frame required in stocking weaving. Supposing the workman has put the work back on the needles, preparatory to another course, the *first* movement is *the gathering of the thread.* The thread is lightly extended across the needles, beneath the nips (*f*) of the sinkers, and by pressing the slur-treadle the jack-sinkers are depressed, one by one, so as to form double loops; this is called drawing the jacks.

The *second* movement is called *sinking.* The whole

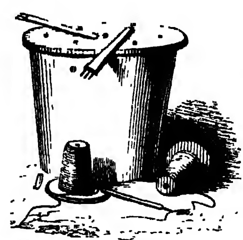
row of lead-sinkers is depressed, while the jack-sinkers rise, whereby the thread is carried down into a loop between every two needles.

The *third* movement is to bring the thread under the barbs of the needles.

The *fourth* movement is to bring the work forward from the stems of the needles towards the barbs.

Fifth, closing the barbs by the pressure of the presser-bar, and drawing the loops last made through the finished loops of the work. The finished loops are drawn over the barbs, and quite off from the needles; this draws the finished loops over the loops last made, which remain in the barbs of the needles.

There are many details respecting the stocking frame, which, for the sake of clearness, have been omitted in the foregoing description. A few of them may now be noticed. The bobbins which supply the workman with thread, are in the case of silk hose contained in a small covered barrel at the side of the frame: this barrel holds a small quantity of water, the evaporation of which keeps the thread sufficiently damp for working. It is drawn out as it is wanted, through a hole in the cover of the barrel.



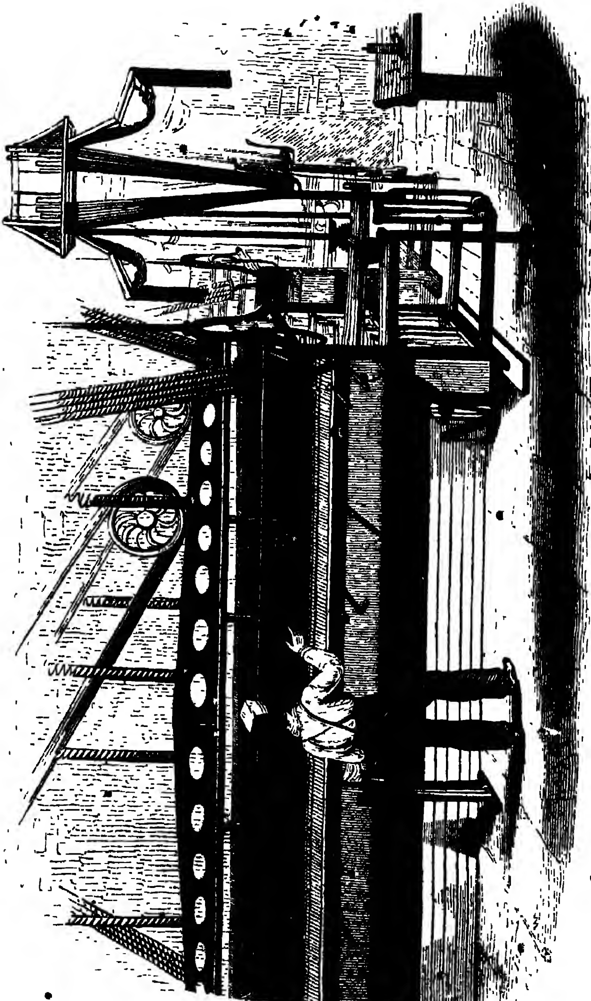
In cotton hose, the bobbin containing the thread is merely placed on an iron spindle, fixed in one of the upright beams of the frame. The jacks with their springs, and the slur-bar, are mounted upon a strong bar called the *camel*, which moves upon four wheels, forming a sort of carriage, capable of being pushed backwards and forwards through a small space. In bringing a row of loops forward, so as to be under the barbs or hooks, the carriage is simply drawn forward, which advances all the sinkers together, and their points (*t*, figs. 5 and 6,) push forwards the thread

till it comes into the barbs, and these prevent it from coming off the needles. The jacks also admit of being depressed by the workman's hand, and they recover their position when relieved, by the action of a steel spring. In pushing the work back upon the stems of the needles so as to come into the arched or open part of the sinkers, the hosier depresses the sinkers low enough for their point (t) to enter between the needles, and then, by pushing the sinkers back, the thread is driven back with them.

The fineness of the work depends on the number of loops which the thread makes in any given length, and this will be equal to the number of needles and sinkers in the same space. The number of needles in an inch is called the gauge of the frame, and when once this is fixed it can never be altered; hence the work which it produces will always be of the same degree of fineness, so that when a stocking-maker has once purchased his frame, he is always limited to the same kind of work; he may, however, make it a little more dense or more slight, by drawing the loops very close, or by allowing a greater quantity of thread, and making the loops longer. The length of the loops will depend upon the depth to which the nips of the sinkers descend between the needles when they carry down the thread into loops. To regulate this depth, the falling bar, or that piece which sustains the leads containing the row of needles, is made to rise or fall a slight quantity, by means of two adjusting screws.

When the piece of work is finished and taken off from the frame, the last made row of loops must be secured by running a thread through them, or by some other means, or they would escape by drawing through the preceding loops, and these in like manner would release the previous ones, until the whole became unravelled.

The working of the frames is one of considerable toil, but does not for ordinary goods require much skill and training. The employment is said to be injurious to the sight.



THE MANUFACTURE OF LACE.

HISTORICAL NOTICE OF LACE, AND OF THE BOBBIN-NET FRAME.

THE word lace is said to be derived from the Latin *lacinia*, the guard hem or fringe of a garment; it is a kind of net-work of threads of gold, silver, silk, flax, or cotton, forming a kind of transparent texture, which, until within a few years, was made at so slow a rate, and consequently sold for so high a price, that it could only be worn by wealthy persons.

The origin of this delicate fabric is very obscure. There is evidence that it was worn by the Grecian ladies, and from the derivation of the word it was probably known to the Romans. It was worn at an early period in Venice, and the neighbouring states of Italy, and it is supposed that Mary of Medicis was the first to introduce it into France; but it was known in England as early as 1483, in which year it is included in a list of articles prohibited to be imported; an act probably intended to favour the home manufacture; but as pins (which were quite necessary in making lace) were not used in England till 1543, the manufacture must have been coarse and limited. There is a tradition that the lace manufacture was introduced into this country by some refugees from Flanders, who settled at Cranfield in Bedfordshire;

"but there is no certain evidence that we are indebted to the Flemings for the original introduction of this beautiful art, although from them we have undoubtedly derived almost all the different manufactures relating to dress. We have however imitated many of their lace fabrics, and greatly improved our manufacture at various periods, from the superior taste displayed in the production of this article in the Low Countries."* In 1640 the lace trade was a flourishing concern in Buckinghamshire, and so greatly had it advanced in England, that by a royal ordonnance in France, passed in 1660, a mark was established upon the thread-lace imported from this country.

Pillow or bobbin-lace, the original manufacture, was usually made of thread or silk woven into a net, the meshes of which formed hexagons, octagons, &c. according to the pattern. This was also ornamented by a thread thicker than the rest, called *gimp*, so interwoven within the meshes as to form flowers, curves, &c. This kind of lace was made on a hard stuffed pillow or cushion, previously covered with the pattern drawn out upon a piece of parchment. The threads are wound upon bobbins, which are small round pieces of wood, with a deep groove in the upper part for receiving the thread, a separate bobbin being used for each thread. In order to form the meshes, pins are stuck into the cushion, and the threads are woven and twisted round them. The pattern on the parchment shows where these pins are to be inserted, and also gives a design for the gimp, to guide the women in placing it, so that it may be interwoven with the fine threads which form the net-work. The work is commenced at the upper part of the cushion, by tying the threads together in pairs; each pair being attached to a pin. The bobbins hang down by their threads on different sides of the cushion,

* From an excellent artice on Lace, contributed by Mr. Robert Stater to M'Culloch's Commercial Dictionary.

but at the commencement of the work they are all put on one side, and are brought to the front side,

PILLOW LACE MAKING.

two pairs at a time, to be twisted together. The woman, with one pair in each hand, twists the bobbins over each other three times, by which the threads of each pair are twisted together, or round each other, and this is done with the assistance of the finger and thumb of each hand at the same moment. This twisting forms the sides of the mesh. The adjacent bobbins of each pair are then interchanged, in order to cross the threads of these bobbins over each other, and to make the bottom of the mesh. This will be the better understood by supposing the four bobbins to be numbered 1, 2, 3, 4. "1 is twisted round 2, and 3 is twisted round 4; then, in order to cross, 2 and 3 are interchanged, so that 1 and 3 come together, and 2 and 4; and the next time that the twisting operation is performed, these pairs of threads will be combined together."*

* Babbage and Barlow, in the Encyclopœdia Metropolitana.

As the meshes or half-meshes are made, they are secured by pins, to prevent the threads from returning. The four bobbins just noticed are done with for the present, and are put on one side of the cushion; the two next pairs are then brought forward, and twisted and crossed in the same way; and the work proceeds in this manner, till a row of meshes is formed sufficient for the breadth of the intended piece of lace, and then the bobbins are all worked over again to make another row.

The women work with great dexterity, but their progress is slow, as may be supposed, when it is stated that as many as from forty-eight to sixty bobbins are required to every inch of breadth, and only one mesh is made at a time. "Taking the threads at fifty per inch, if the piece of lace is one inch wide, it will have twenty-five meshes in the breadth, or 625 meshes in each square inch of length, or 22,000 meshes in a yard, and the price of a piece of lace of this description is seldom more than eighteen pence."

Mr. Slater enumerates the most celebrated laces as follows:—1. *Brussels*, the most valuable, and of which there are two kinds; *Brussels ground*, having a hexagon mesh, formed by platting and twisting four threads of flax to a perpendicular line of mesh; and *Brussels wire ground*, made of silk, of which the meshes are partly straight and partly arched. In both cases the pattern is worked separately, and set on by the needle. 2. *Mechlin*; a hexagon mesh, formed of three flax threads, twisted or platted to a perpendicular line or pillar. The pattern is worked in the net. 3. *Valenciennes*, an irregular hexagon, formed of two threads, partly twisted and platted at the top of the mesh. The pattern is worked in the net. 4. *Lisle*, a diamond mesh, formed of two threads, platted to a pillar. 5. *Alençon*, called *blond*; hexagon of two threads, twisted, similar to Buckingham lace, and is considered the most inferior of any made on the cushion. 6. *Alen-*

çon Point; formed of two threads to a pillar, with octagon and square meshes alternately.

The lace represented in the portraits painted by Vandyke in the time of Charles I., and afterwards by Sir Peter Lely and Sir Godfrey Kneller, in the succeeding reigns, is of the kind called *Brussels Point*, in which the net-work is made by bone-bobbins on the pillow, and the pattern worked with the needle. It has been supposed that the first lace ever made in this country, was of this kind. "About a century since, the *grounds* in use were the old Mechlin, and what the trade termed the *wire ground*, which was very similar, if not identical, with the *modern* Mechlin, the principal article in the present French manufacture. The laces made in these grounds were singularly rich and durable; the designs of the *old Mechlin* resembled the figures commonly introduced in ornamental carving. Between seventy and eighty years ago, a great diminution was occasioned by the introduction of the *Trolly* ground, which was exceedingly coarse and vulgar, the figures angular, and altogether in the worst taste. An improvement, however, took place about the year 1770, when the ground which is probably the most ancient known, was re-introduced; this was no other than the one still in partial use, and denominated the *old French ground*. About 1777, or 1778, quite a *new* ground was attempted by the inhabitants of Buckingham and its neighbourhood, which quickly superseded all the others; this was the *point ground*, which had (as is supposed) been imported from the Netherlands. From the first appearance of this ground may be dated the origin of the modern pillow lace trade; but it was not until the beginning of the present century that the most striking improvements were made; for during the last quarter of the eighteenth century, the article, though certainly much more light and elegant from the construction of the ground, was poor and spiritless in the design. Soon after the year

1800, a freer and bolder style was adopted; and from that time to 1812, the improvement and consequent success were astonishing. At Honiton, in Devon, the manufacture had arrived at that perfection, was so tasteful in the design, and so delicate and beautiful in the workmanship, as not to be excelled even by the best specimens of Brussels lace. During the late war, veils of this lace were sold in London at from twenty to a hundred guineas; they are now sold from eight to fifteen guineas. The effects of the competition of machinery, however, were about this time felt; and in 1815, the broad laces began to be superseded by the new manufacture. The pillow lace trade has since been gradually dwindling into insignificance."* It is not easy to estimate the number of persons employed in making pillow lace, when the trade was most prosperous; but in a petition from the makers in Buckingham and its neighbourhood, presented to Queen Adelaide in 1830, it was stated that one hundred and twenty thousand persons were dependent on this trade; but the number has since been greatly reduced.

It is said that lace was made by machinery so early as the year 1768, by a stocking weaver of Nottingham, named Hammond. Being of dissipated habits, and without money, credit, or employment, the idea occurred to him, while looking at the pillow lace on his wife's cap, that he could make such an article by means of his stocking frame. He appears to have succeeded in producing a machine which was called a *pin machine*, for making single press *point* net, in imitation of Brussels ground. This machine is no longer used in England, but is in use in France in the manufacture of net called *tulle*. Hammond's success stimulated other workmen to investigate the lace-making capabilities of the stocking frame; and it soon became a common amusement of their leisure

* See the concluding paragraph, p. 48, supra.

hours to form new meshes on the hand, in the hope of finding a method of producing a complete hexagon, a thing not as yet accomplished. The *warp frame*, for making *warp lace*, was introduced in 1782, and in 1799 was made the first attempt to make *bobbin net* by machinery. These contrivances enabled the stocking weavers to produce an inferior kind of lace with such facility that they could greatly undersell the pillow lace makers, whereby the demand for lace was increased, and Nottingham soon became the centre of a new and thriving trade.

The attempt to produce bobbin net by machinery does not appear to have been successful until the year 1809, when Mr. Heathcoat obtained a patent for a frame, which is said to have been suggested, if not invented, by a workman employed in making machinery for producing fishing nets, who, taking advantage of a hint which was given to him by a child at play, was led to the idea of making lace by warp and weft, by arranging the warp threads in parallel lines, and disposing the diagonal weft threads upon small detached bobbins, capable of passing round the extended warp threads, so as to twist with them. At a trial in one of the courts of law, to which this patent gave rise, Mr. Brunel, the engineer, appeared as witness, and said, that when the inventor had separated one half of the threads, and placed them on a beam as warp threads, and made the bobbins which carried the other half of the threads act between those warp threads, so as to produce Buckingham or pillow lace, the lace machine was invented.*

This invention having seriously affected the manufacturers of pillow lace, the new machines became the object of attack by the workmen, who, under the

* In a note to this paragraph by Mr. Felkin, who kindly revised this treatise preparatory to publication, he says—"After many months' laborious research, I can find not any ground to doubt that Heathcoat was the real inventor of the machine for making twisted lace: to him Brunel refers."

name of "Luddites," maintained for a considerable time a combination against them. Mr. Heathcoat removed to Devonshire, where he raised the bobbin-net manufacture into importance. On the expiration of his patent, in 1823, the manufacture revived at Nottingham. Persons of all classes embarked their capital in the lace manufacture; "prices fell in proportion as production increased; but the demand was immense; and the Nottingham lace frame became the organ of general supply, rivalling and supplanting, in plain nets, the most finished productions of France and the Netherlands." The earnings of the work-people were enormous, "and it was no uncommon thing for an artisan to leave his usual calling, and betaking himself to a lace frame, of which he was part proprietor, realize by working upon it 20*s.* 30*s.* nay, even 40*s.* per day. In consequence of such wonderful gains, Nottingham, the birth-place of this new art, with Loughborough, and the adjoining villages, became the scene of an epidemic mania. Many, though nearly devoid of mechanical genius, or the constructive talent, tormented themselves night and day with projects of bobbins, pushers, lockers, point-bars, and needles of every various form, till their minds got permanently bewildered. Several lost their senses altogether; and some, after cherishing visions of wealth, as in the old time of alchemy, finding their schemes abortive, sank into despair, and committed suicide."*

Such sad examples as these were sufficient to check ignorant enthusiasm, and gradually the trade began to flow in a healthier stream. The machine still became the subject of changes and improvements, and in 1816 it was first worked by steam power. The effect of all this has been to place the luxury of lace within reach of all classes. The machine patented by Mr. Heathcoat greatly lowered the price

* Ure's Cotton Manufacture of Great Britain. Vol. II.

of lace; but the lace for which he charged five guineas a yard, can now be had for eighteen pence! Quillings sold in 1810 at four shillings and sixpence a yard, can now be had of better quality at three halfpence! Many other similar instances might be given of the effects produced by the introduction of automatic machinery into the lace manufacture.

Another curious effect of this machinery for some years after its introduction was, that, instead of smuggling French lace into England, as was formerly done to a very great extent, English lace was largely smuggled into France. At the present time, however, the quantity of lace made by machinery abroad is nearly equal to that which is produced in this country.

LACE MAKING BY MACHINERY.

The difference between weaving and lace-making may be seen at a glance by reference to the following figures. In the first, which is illustrative of

Figure 1

plain weaving, the black dots represent the warp threads, and the waving line the weft, which passes regularly over and under the warp threads in succession. In the second figure the weft passes over three

Figure 2.

threads and under one; this is twilled weaving, by means of which various patterns are produced with white threads alone. The third figure is intended

Figure 3

to illustrate the structure of *gauze.** The essential character of gauze weaving is, that between each cast of the shuttle the warp threads are made to cross each other, whereby the weft threads (represented in this figure by the black dots) are separated from each other, and a firm but transparent texture produced. The fourth figure is different from all these: in this

Figure 4

the threads of the weft are *twisted* round those of the warp; this twisting being the distinguishing operation between weaving and lace making.

If we examine a piece of lace, it will be found that

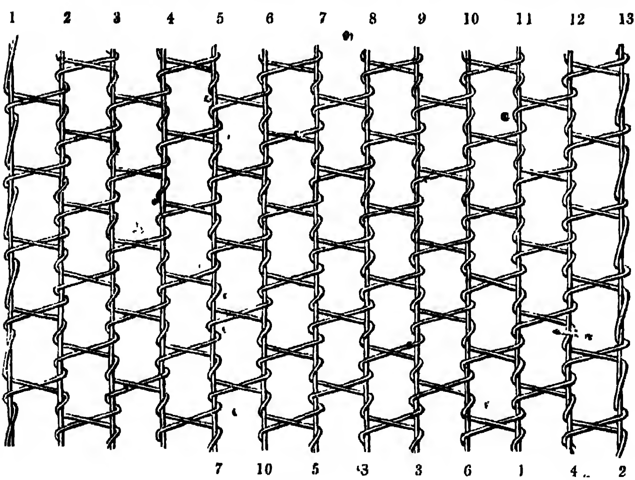


Figure 5.

while a series of warp threads proceed in one direction nearly parallel to each other, as in plain weaving,

* Supposed to have been first invented in Gaza, a city of Palestine: whence the name.

the weft threads are inserted in quite a different way. If we suppose the warp threads to be quite straight, as in figure 5, it will be easy to trace the course of the weft, as it proceeds in a double series in opposite directions across the warp. Each weft thread twists once round each warp thread until it reaches the outermost one, when it makes two turns, proceeding after the second turn towards the other border in a reverse direction. By means of this double twist and the return of the weft threads the selvage is formed.

In the above example the warp threads are supposed to be straight and parallel. Such, however, is not the case in practice, the twisting and interlacing of the threads producing regular six-sided meshes. The accompanying specimens show, upon a magnified

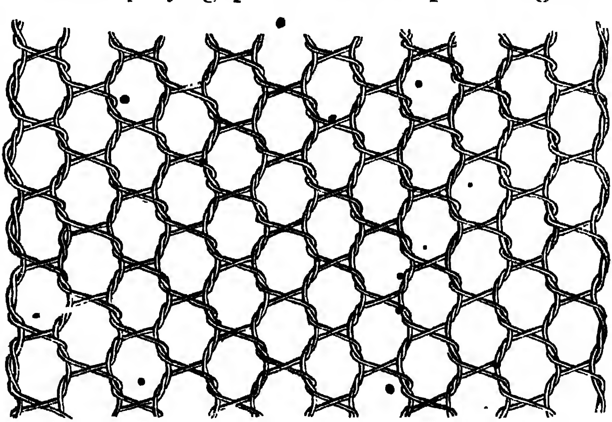


Figure 6.

scale, how the fabric is produced by the union of three sets of threads, one of which proceeds from the top downwards in a waving line, the second set runs towards the right, and the third to the left, crossing each other obliquely in the centre between each two meshes throughout the series. The warp threads

form in the first instance parallel straight lines, as in Fig. 4, and they derive their curvature from the tension of the oblique weft threads, one set of which draws them to the right, and the other set to the left. After the warp threads have been laced or entwined

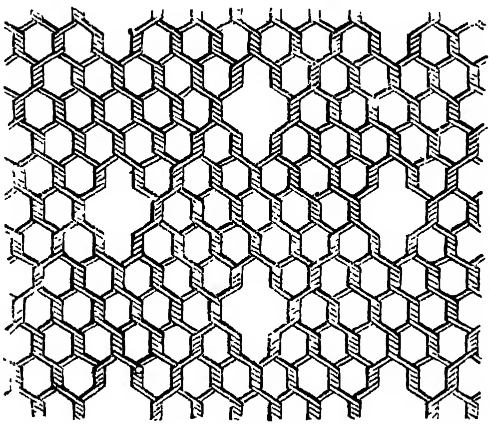


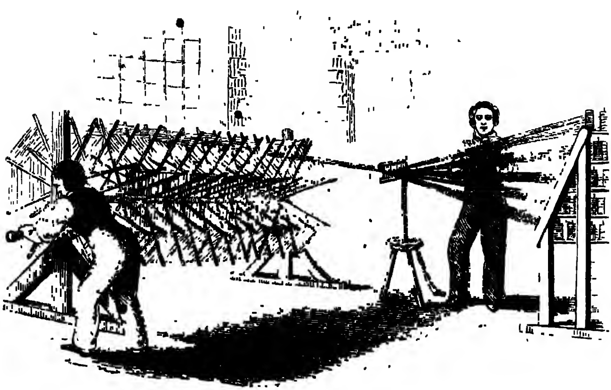
Figure 7.

twelve times with a weft thread (Fig. 4. 2, 2. 13, 13), the latter moves sideways through one interval of the warp thread, and if it were coloured would produce in the course of the work a diagonal line across it. The manufacture of lace, therefore, differs from plain weaving in this, that the threads of the warp are not alternately raised and depressed for the purpose of introducing the weft, but are shifted sideways to the next pair, to which they become united by the weft threads, working likewise in pairs, each of them entwining two individual threads at once.

The lace frame is perhaps the most complicated machine in the whole range of manufactures. In order to convey a clear idea of its action we shall select for description only the most important parts, referring the reader who is desirous of obtaining

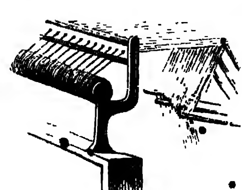
more complete information to the second volume of Dr. Ure's work on the cotton manufacture; which contains a very minute account of Morley's circular bolt bobbin net lace frame.

The thread used in the lace frame is wound upon a roller to form the warp, and upon a number of small bobbins to form the weft. The operation of



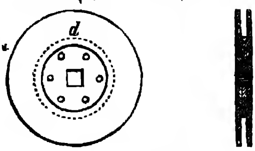
WARPING.

warping is in many respects similar to that already described for weaving, except that the reel upon which the threads are wound is placed horizontally instead of upright; the threads are passed through a jack in order to distribute them evenly over the reel, and as the length of this reel is considerable, only a portion of it is covered at once. When the reel has taken up all the thread, the latter is transferred to a roller or thread beam, which extends the whole length of the lace frame.



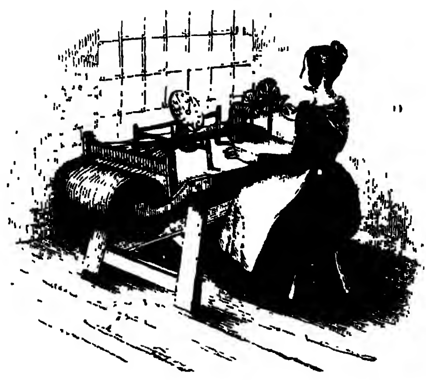
The weft threads which are to pass through the intervals of the warp are wound upon

little bobbins, one of which is shown in view and in section. It is formed of two thin brass disks with a hollow in the middle of each; the two disks being rivetted together so as to leave a circular groove between them for receiving the thread. In the centre is a square hole, for receiving a spindle rod of the same shape, in order to prevent them from turning round the rod in the process of winding in the thread preparatory to their introduction into the lace machine.



WEFT BOBBIN.

The threads are wound upon the bobbins by an ingenious apparatus, by means of which as many as

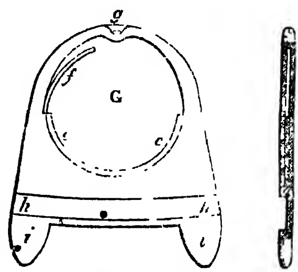


FILLING THE BOBBINS.

from one hundred to two hundred bobbins may be filled at once. The thread being previously wound upon a drum, its ends are passed through slits in two slips of brass plate, these slits corresponding to the number of bobbins to be filled. The rod containing the bobbins is turned round with a handle, which causes the drum to revolve and deliver its thread. The surface of the table over which the train of

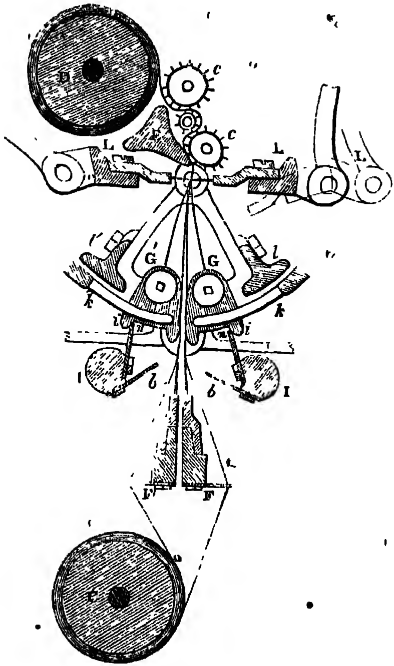
thread passes is painted black, so that the young woman who winds instantly notices when a thread happens to break. As many as twelve hundred of these bobbins are often required in one machine, and in order that they may be filled each time with the same quantity of thread, usually about a hundred yards, a hand moving round a dial plate indicates the number of turns made by the bobbins, and consequently the quantity of thread wound.

The bobbins being filled with thread, each is inserted within a little iron frame called the bobbin carriage, shown in the following figures in view and in section, about half the actual size. The bobbin is inserted into the hole of the carriage G, the grooved borders of the bobbin fitting the narrow edge *e e* of the hole, and being prevented from falling out by the pressure of a spring *f*, which is not too strong to prevent the bobbin from turning round and giving off its thread when gently pulled. The thread is conducted through the eye *g* at the top of the carriage, in order to be wound off in making the lace.



BOBBIN CARRIAGE.

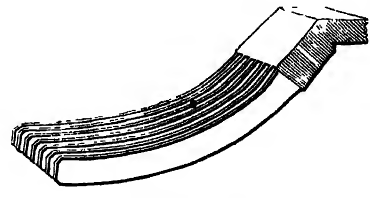
Let us now endeavour to describe the most important parts of the lace frame and their mode of action. The following diagram is a vertical section, giving an end view of the parts indicated. C is the roller or thread beam containing the warp thread. At the top of the frame is a similar roller D on which the finished work is wound. Between these two rollers the warp threads are extended in perpendicular lines. F F are guide bars, extending the whole length of the machine, with slits in their edges, through which the warp threads are conducted in two rows, one on each side to the eyes *b b* of needles, one of which is shown



in the following figure. Each guide bar, which contains a range of these needles, equal to one half the number of threads in the warp, is capable of *shogging*, that is, shifting slightly to the right or to the left to allow the bobbin threads to pass on the right or on the left of the warp threads as many times as is necessary to produce the twist.

The number of bobbins with their carriages is equal to the number of the weft threads, and as these have to pass through the narrow intervals of the warp threads, they are arranged in a double line in two rows, shown at G G, on each side of the warp threads.

The bobbins are supported between the teeth of a sort of comb shown at *k k*, and a portion of it separately in the following figure; for which purpose the bobbin carriages are each furnished with a groove (*h h* Fig. 37), corresponding to the interval between the teeth of the comb. There is one comb on each side of the warp; and the free ends of the teeth in the opposite combs stand so near to each other, as to leave room merely for the proper motions of the warp threads between them. Hence the carriages in passing across through the intervals of the warp, reach the back bolts before they have entirely quitted the front ones.



PORTION OF COMB.

The carriages are driven alternately from one comb to the other by two bars *l l*, and when one of the lines of carriages is pushed nearly across the intervals of the warp, the foremost of their projecting catches *i i* is laid hold of by a plate *n* attached to a horizontal shaft I, which pushes it quite through.

The beam to which the combs are attached admits of being shifted a little sideways, either to the right or to the left; by which motion the relative position of the opposite combs is changed by one interval or tooth, so as to transfer the carriages to the next adjoining teeth. By this means the whole series of carriages makes a succession of side steps, to the right in one comb and to the left in the other, so as to perform a species of countermarch, in the course of which they are made to cross each other, and then again to twist round about the vertical warp threads, and thus to form the meshes of the net.

After the bobbins have moved several times round about the warp threads, and entwined their threads

with them, a point bar L, containing a row of pointed needles, falls between the warp and weft threads, and carries the interlacements of the latter up to form a new line of holes or meshes in the lace. Here it remains, while the other point bar makes a similar movement to produce a second line of meshes. Thus the whole working of the machine is a constant repetition of twisting, crossing, and taking up the meshes on the point bar. As the lace is finished it is wound upon the roller D.

If the reader has followed these details with some degree of attention, he will be able to form a pretty accurate idea of the manner of interlacing the threads of the warp and the weft, so as to produce lace.

The beauty of bobbin-net lace depends on the quality of the threads, and also upon the meshes being of equal size and of a truly hexagonal shape. The nearer the warp threads are together, the smaller are the meshes and the finer is the lace. The number of warp threads in a piece one yard wide, may vary from 700 to 1200. The fineness of the lace, or as it is called the *gauge* or *points*, depends on the number of slits or openings in the combs, and consequently the number of bobbins in an inch of the double tier. Thus gauge nine-points means nine openings in one inch of the comb.

The length of work, counted perpendicularly, which contains 240 holes or meshes, is called a *rack*. Well, made lace has the meshes slightly elongated in the direction of the selvage. A circular bolt machine produces about 360 racks per week, working eighteen hours a day, with two sets of superintendents.

Bobbin net is usually sent into the market in pieces of from twenty to thirty or more yards in length. The breadth is very variable. The narrow *quillings* used for cap borders, of about the breadth of the finger or somewhat more, are worked in the same machine in many breadths at once. They are all

united together by a set of threads, which being afterwards drawn out, the quillings become so many distinct pieces.

The English machine-made net is now confined to *point net, warp net,* and *bobbin net,* so called from the peculiar construction of the machines by which they are produced.

In Mr. Beck's establishment at Nottingham, the machines employed are limited to the making of fancy net, both in wide pieces and in quillings, the thicker thread or gimp being wrought into the desired pattern by means of a Jacquard apparatus attached to the frame. (See Frontispiece, p. 22.) When the desired pattern consists of a series of separate flowers, sprigs, &c., these are necessarily all connected by a single thread of gimp passing between them, which single thread is afterwards cut out by children, whose keen eyes and nimble fingers enable them to use the scissors with great precision and rapidity. Many establishments, however, produce only plain net, into which the pattern is afterwards worked by hand.

Nottingham has its pattern designers for lace, as well as Manchester for cottons. The lace pattern is drawn upon a block of wood, and then engraved in the same manner as a wood engraving, those parts of the surface being left in relief which are intended to make a mark. The block is slightly moistened with some coloured pigment, and is then impressed upon the net a sufficient number of times to cover its surface. The lace runner then fills up the pattern with her needle, the web being extended horizontally in a frame for the purpose.

Lace running is a domestic employment, and the young females engaged in it are very badly paid. Mr. Slater says, that even for the most splendid and beautiful specimens of embroidery, some of which have occupied six weeks, working six days a week and fourteen hours a day, the young women did not earn more than one shilling a day. He is inclined

to attribute the depressed condition of the embroiderers, in a great measure, to the competition of the Belgians, who have acquired a superiority in this department.

When the lace is embroidered it is carefully examined, and all defective parts marked by tying them up in a knot; the piece is then handed over to women called *lace menders*, who have a method of perfectly restoring the damaged meshes. The lace menders are a much better paid class than the lace runners.

The net is gassed before being embroidered; the bleaching or dyeing takes place afterwards; the dressing, rolling, pressing, ticketing, and making up, so closely resemble similar processes already described for muslin, that no further notice of them is necessary in this place.

STATISTICS OF HOSIERY AND LACE

THE hosiery and lace trades occupy a large population in the great midland district, extending from Leicester northward, to Chesterfield, and from Nottingham westward to Derby and Hinckley. Nottingham is the centre of the cotton and silk hosiery trade; Leicester of the woollen hosiery; and Derby has about the same amount of the silk hosiery trade as Nottingham. Nottingham is also the centre and the depôt of the machine-lace trade, although it is carried on, not only in the surrounding towns and villages, but also in Somersetshire, Devon, Wilts, Gloucestershire, and the Isle of Wight. From all these places it is collected at Nottingham, and thence distributed to various parts of the world.

In February, 1844, a Royal commission was issued for an inquiry into the condition of the frame-work knitters in the counties of Leicester, Nottingham, and Derby. The report of the commissioner, R. M. Muggeridge, Esq., has just been published.

This valuable document, (which, including appendices, containing minutes of evidence, extends to 1053 folio pages,) contains a vast amount of information on all subjects connected with the hosiery trade; in collecting which the commissioner visited not only the principal seats of the frame-work knitting manufacture, but also as many of the villages and smaller towns where the trade is carried on, as placed within the reach of nearly every workman in the three counties the opportunity of laying before the commissioner any statement he desired. "The total number of persons examined exceeded 600, embracing workmen and employers, in every one of the almost infinite variety of branches into which the hosiery manufacture is divided, and selected from every district in which it is carried on in the counties to which the jurisdiction of my commission extended."

It appears from this evidence, that until a very recent period the workmen were frequently paid in goods instead of money, and that although this practice has been made illegal, it is still carried on by a large class of employers, who combine with their occupation in the manufacture, shops for the sale of provisions, which they compel the workmen to purchase. That the frame-work knitters as a body are in a very depressed and distressed state, from the very low amount of their ordinary earnings. That the chief cause of the low rate of wages is the superabundant supply of labour, arising from the facility with which a knowledge of the trade is acquired by women and children, as well as by the ordinary workmen. That this excess of supply is encouraged by the system of frame rents, and the custom of heavy deductions on several pretexts from the wages of the work-people; which make it the interest of employers to spread any given amount of work among a larger number of workmen than is necessary to its performance; a practice that is further greatly facilitated by the superabundant amount of machinery

which has been created and brought into the trade by others than the legitimate employers in it, as profitable investments of capital, induced by the customary exorbitant rent of the frames.

That no permanent or general improvement in the condition of the frame-work knitter can be looked for but by a diminution of their numbers proportionate to the existing demand for their labour; or such an extension of the manufacture as would largely increase the amount of employment. The first of these means can only be produced by the workmen abstaining from early or improvident marriages, or by bringing up their families to other occupations.

That an extension of the manufacture is most likely to be attained by the improvement of which it appears susceptible in the manner of conducting it, by a more judicious appropriation and division of labour, whereby the cost of production would be diminished; and by an increased application of taste and skill in the designs and patterns of the articles manufactured, especially in the fancy branches of the trade.

That an improvement in the quality of most of the goods manufactured is apparently as essential to an increase of permanent demand, as it will, probably, soon be found to be to the maintenance of the manufacture, even at its present extent; the evidence tending to establish that the spurious qualities of a large proportion of the goods made, is calculated to lower the character of the manufacture, both at home and abroad.

At the meeting of the British Association at York, in the year 1844, Mr. Felkin read an interesting paper on the statistics of the hosiery manufactured by machinery in the United Kingdom, compiled from an actual census taken under his direction in the same year.

There are about 42,652 persons engaged in the manufacture of stockings, and as many more are employed

to wind, seam, and sew up the hose. Mr. Felkin denied that as a class they are idle and negligent; he had known them from boyhood, having worked for his support at their frames, and he knew that they were no worse than hard work and small wages would make any class of the community. Foreign competition has had little effect upon this branch of industry, for the amount of the exportation of hosiery has never been important. There were only 147,507 dozens exported in 1843, and that was nearly double the amount of the preceding year.

The total number of frames in the three midland counties is 39,442 employed, and 4,598 unemployed. There are 1,572 frames in the rest of England, 265 in Ireland, and 2,605 in Scotland; and taking the whole of Great Britain, there are 42,632 employed, and 5,830 unemployed, (many of the latter, however, being under repair,) making a total of 48,482 frames available for the machinery of the trade.

The earnings of the frame-work knitters are subject to heavy deductions for the rent of frames and other incidents, which frequently reduce the net earnings to a most miserable sum. The earnings, clear of shop deductions and expenses, range generally from 4*s*. 6*d*. to 7*s*. per week, and in some places where cotton hose is chiefly made, wages are even lower than the above minimum. The general condition of the frame-work knitters is described as very deplorable; they work generally from fourteen to fifteen hours a day, and their net earnings are generally inadequate to procure subsistence for themselves and their families.

There are manufactured annually in Great Britain 84,000 dozens of silk stockings and socks; 2,164,000 of cotton, and 1,770,000 of worsted. Including gloves and other hosiery products, the annual production is 5,705,600 dozens, which would not give more than one pair of stockings and one pair of gloves for each inhabitant of Britain. The raw materials employed in this production, both imported

and of home growth, are of the collective value of 705,900*l.* sterling; which materials are raised by labour to the selling value of 2,562,713*l.*

In a memorial to the Lords of the Treasury in 1834, from the Nottingham manufacturers, it was stated that Heathcoat's machine had twenty-four motions to the series for twisting the mesh, and four motions for the pins to secure the twist from unravelling. Before the expiration of the patent, this machine was simplified so as to require only thirteen motions to complete the same mesh, and two to prevent the unravelment; other improvements reduced the motions to thirteen, and at length the utmost acme of speed was accomplished by reducing the motions to six, and performing the two motions to prevent unravelment at the same time that the other motions were made. The original machine produced only one rack in an hour, whilst the power-impelled machines can make six such racks in an hour; in addition to which the original machines made nets from one yard to one yard and a half in width, whereas machines are now made to fabricate net three and even [illegible] yards in width, thus increasing the speed of the machinery twelve-fold. The result of all these improvements has been to convert England into a great exporting nation for lace, to the amount of two millions annually, instead of being an importing nation to nearly that amount.

The annual produce of lace was estimated, in the year 1831, at 23,000,000 square yards, of the value of 1,891,875*l.* In 1840, in consequence of the introduction of new and improved machinery, a larger quantity was produced at a lower rate; amounting to 30,771,000 square yards, worth 1,850,650*l.* The raw material used in the production of the latter quantity has been estimated at 1,270,000lbs. of Sea-Island cotton, worth 148,000*l.* and thrown silk to the value of about 10,000*l.** On comparing the cost of the raw materials with the manufactured

* Felkin.

value of the same, the national importance of the lace trade can be at once estimated. "A clear surplus of more than a pound sterling is realized upon every pound weight of the raw material, which is distributed over the trade in rent, profits, and wages; and this is altogether independent of the profits arising from embroidery, in itself a most important and extensive branch."*

The lace frames are worked either by steam power or by hand. In the one case, a considerable number of frames are collected together in a large factory, which is conducted on the usual factory system; in the other case, a single individual may be the owner of a single machine, which he works himself. "It is not uncommon to find one of these costly machines, which may have occasioned an outlay of from 500*l.* to 1,000*l.*, within a house but little removed above the degree of a cottage; but for the most part they are worked in the attics and upper stories of substantial houses, the lower parts of which are occupied as shops or lodging houses. The centre of the town [Nottingham] is not much filled with them; but in all the approaches, and in the back streets, as well as in the better houses of the lower town, the incessant thumping of the machine is heard."†

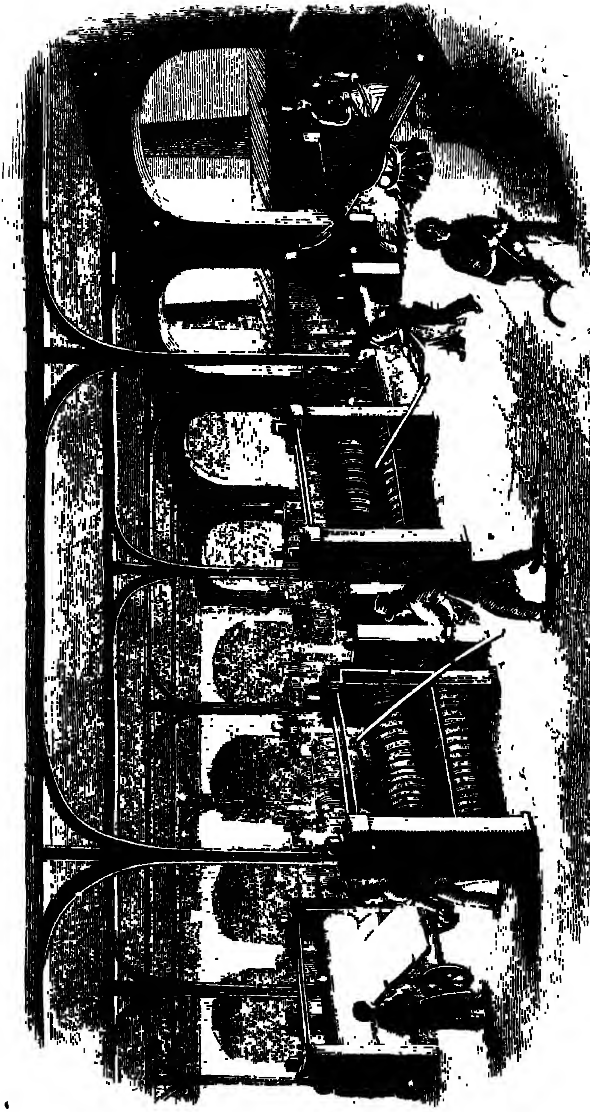
Respecting the health of the work-people engaged in the lace trade, those in the factories are most favourably situated; the rooms are large and well ventilated, and the people have merely to superintend the machines. When the machines are worked by hand, the labour is severe; but as there are usually two sets of men to hand machines, one set seldom works more than six hours a day. The embroidery frame is perhaps the most destructive. Mr. Slater says, "The workers in general commence at a tender age, and from constantly leaning over the frame

* Slater.
† Factory Commissioners' Report.

while their bodies remain in a state of inactivity, they are frequently distorted in their persons and become the victims of pulmonary disease. Notwithstanding the sedentary habits of the pillow lace makers, their general health is understood to be better than that of the lace embroiderers, but in both these employments the hours of labour are too long for the children.

"They are, however, purely domestic employments, under the superintendence of parents; but as the existence of the latter depends on the quantity of labour they can bring into operation, their necessities place filial considerations beyond the reach of legislation or even social interference."

At the time when Mr. Slater wrote, the pillow lace workers were in a very depressed state, not being able to earn more than half-a-crown a week each, although toiling every day for twelve or fourteen hours; whereas, some years before, they could with ease earn ten shillings a week, working only eight hours a day. Recently, however, the taste for pillow lace has revived; and we learn from Mr. Felkin that, at the present time, the pillow lace trade of Devonshire and Buckinghamshire is increasing and active, and still more so in Belgium.



THE USEFUL ARTS

AND

MANUFACTURES OF GREAT BRITAIN.

THE MANUFACTURE OF IRON.

THE splendid colour of GOLD, its great density, its imperishable nature, and its comparative scarcity, have obtained for it the epithet of *precious*, although, in point of utility to man, IRON has far higher and more numerous claims to such a title. Its ore, scattered through the crust of the earth in inexhaustible profusion,—often in immediate connexion with the fuel requisite for its reduction, and the limestone which facilitates that reduction,—"is an instance of arrangement, so happily suited to the purposes of human industry, that it can hardly be considered as recurring unnecessarily to final causes, if we conceive that this distribution of the rude materials of the earth was determined with a view to the convenience of its inhabitants."*

The innumerable applications of iron in our own day result from the various useful properties of this metal: it can be brought to a fluid state, and made to assume whatever form has been given to the mould designed to receive it; it can be drawn out into bars of any degree of strength, or into wires of

* Conybeare, Geology of England and Wales.

any degree of fineness; it can be spread out into plates or sheets; it can be twisted and bent in all directions; it can be made hard or soft, sharp or blunt. Iron may be regarded as the parent of agriculture, and of the useful arts; for without iron, the ploughshare could not have rendered the earth fertile. Iron furnishes the scythe and the pruning-hook, as well as the sword and the cannon; it forms the chisel, the needle, and the graver; springs of various kinds, from the spring of a watch to that of a carriage; the chain, the anchor, and the compass, all owe their origin to this most useful of all the metals. We can scarcely move without meeting with new and surprising proofs of the fact, that we are, indeed, living in the age of iron. We travel by land on iron railroads, drawn by horses of iron; we pass over bridges constructed of iron, and often suspended by iron rods; our steam-boats are of iron; our bedsteads, chairs, stools, and ornaments are frequently of iron; clumsy wooden gates are superseded by light and elegant structures of iron; buildings of all kinds are supported on pillars of iron; and, to crown all, we build houses and light-houses of iron, and transport them in pieces to the most distant parts of the globe.

Iron, therefore, performing so important a part in the progress of civilization, may well deserve a somewhat extended notice; and it is proposed, without departing from the plan of former treatises, to preface the account of the manufacture with a somewhat detailed account of the metal, from the earliest times.

HISTORICAL NOTICES OF IRON.

In the early history of the world, the use of iron seems to have been known; for we read (Gen. iv. 22.) of Tubal Cain, an instructor of every artificer in brass and iron. From an expression in Deuteronomy iv.

20, "the Lord hath brought you forth out of the *iron furnace*, even out of Egypt," it appears more than probable that the smelting and working of iron was commonly practised in that country. In the same book, Palestine is described as "a land whose stones are iron, and out of whose hills thou mayest dig brass." (Deut. viii. 9.) There are, also, several passages in the four books of the Mosaic law which prove that iron was well known. The bedstead of Og, King of Bashan, was of iron. (Deut. iii. 11.) Iron tools were used in hewing and squaring of stones. (Deut. xxvii. 5.) Saws, harrows, and axe-heads, were of iron; and it is probable that offensive weapons were made of the same metal, because it is stated in the Mosaic law, that "If any one smite another with an instrument of *iron* so that he die, he is a murderer." The chariots of the Philistines were of iron. (Judges i. 19.) And Jabin, King of Canaan, reduced the Israelites to subjection by means of his nine hundred chariots of iron. (Judges iv. 3.) "These chariots were probably war-carts, with perhaps scythes attached to the axles of their wheels, such as were in use by the sovereigns of Assyria and Mesopotamia, and whose charge on level ground could not fail of being extremely formidable to infantry, of which the Israelitish armies, before the appointment of kings, appear entirely to have consisted."* Goliath is represented as wearing bronze armour, and a spear pointed with iron; and in the hymn of victory composed by David, after the reduction of all his enemies, mention is made of a bow of steel. (2 Samuel xxii. 35.)

"Previous to the Babylonian conquest, the Jews were acquainted with two kinds of iron; namely, that in common use, and a much superior sort, known by the name of northern iron." Thus, in Jeremiah

* AIKIN, *Antiquarian History of Iron*, in the Transactions of the Society for the Encouragement of Arts, Manufactures, and Commerce.

xv. 12, "Shall iron break the northern iron and the steel?" Mr. Aikin thinks that the *steel* here meant, was the produce of the countries east of Babylonia. In the book of Ezekiel, xxvii. 12—19. in the "Lamentation for Tyre," the different countries are enumerated with which this great emporium traded, and the commodities which she imported from them. It is declared of Tyre, that "Tarshish was thy merchant, by reason of the multitude of all kind of riches; with silver, iron, tin, and lead, they traded in thy fairs." It is generally agreed, that by Tarshish is meant Spain, the maritime town of Tartessus, at the mouth of the Guadalquiver, still affording some probable indication of the name. "It was probably in part from Celtiberia, and in part from Catalonia, a district between the lower Ebro and the Pyrenees, celebrated in all times for its iron, that this metal was imported to the Tyrian markets: and I may observe here, that the old Catalonian method of obtaining bar-iron directly from the ore, without going through the usual process of smelting, and which, even now, is hardly obsolete in that province, is, from its character of rude simplicity, not unlikely to be the very process made use of for the supply of the Tyrian market, 2,300 years ago."

It is mentioned in another passage: "Dan also, and Javan, going to and fro, occupied in thy fairs; *bright iron*, cassia, and calamus, were in thy market."

The term *bright*, applied to this iron, seems to distinguish it from common iron; and the same merchants who brought this, brought also cassia and calamus, two aromatic substances, probably obtained from the countries to the east of Persia, whence they were brought by land carriage in caravans, "going to and fro." "If this *bright iron* were the common malleable form of this metal, it could never have entered into competition with the iron of Tarshish, conveyed by water carriage; we may, therefore, I think, without any great chance of error, regard it as the *northern*

iron or steel, already mentioned, susceptible of a bright polish, and perhaps not differing from the *wootz* of modern India."

Among the ancient Greeks bronze seems to have preceded the use of iron; and the term used to designate the smith's calling signified a "worker in bronze;" a term which, in the course of time, came to be applied to workers in iron also. Iron is frequently mentioned by Hesiod, who characterizes the four ages of the human race as the golden age, the silver age, the brazen age, and the *iron* age. The uses to which iron was applied are noticed in many passages of Homer. "Iron was used for felling-axes, for double-headed axes for slaughtering cattle, for shipwrights' tools, for the axles of chariots, for pointing ploughs, for sheep hooks, and agricultural implements. In exchange for cargoes of wine supplied to the camp before Troy, bronze and iron were given. Among the spoils gained by Achilles in sacking the towns of the Trojan allies, were gold, ruddy bronze, and white iron." And to remove all doubt as to the correct rendering of the word σιδηρος into iron, Mr. Aikin quotes the following simile from the Odyssey:—"As some smith* plunges into cold water a loudly-hissing great hatchet or adze, tempering it, for hence is the strength of iron;" clearly proving that the art of tempering steel was practised just as it is at the present day for common cutting tools, and that the worker in iron or steel was called a brazier.

The use of iron is also noticed by Herodotus, Æschylus, and other Greek writers. About the time of Æschylus (who was born 460 years B.C.), steel of excellent quality seems to have become so abundant in Greece, as to have superseded the use of bronze for swords and other offensive arms. "In the imperfect geography of the Greeks, all the countries on the shores of the Black Sea, and thence indefinitely

* "Worker in bronze" is the original word

northward and eastward, were confounded together under the general term Scythia; hence Chalybian and Scythian are used by Æschylus indifferently. He speaks of the Chalybes as workers in iron, of Scythia as a land the mother of iron; and of the sword as 'sharp iron, the bitter appeaser of strife, the Pontic stranger born in fire,' and also as 'the Chalybian stranger come out of Scythia.' From this time dates the use of the word chalybs, in Greek, as signifying steel of the best quality; whence it passed, unchanged, into the Latin language, and may at the present day be recognised in our own in the expression *chalybeate* waters, *chalybeate* medicines, &c., in consequence of some commercial transactions which took place more than twenty-three centuries ago, between Greece and a country on the Black Sea."

Aristotle seems to have entertained the incorrect notion that steel was only the purest state of iron. He says:—"Steel is made by melting wrought iron, and then letting it become solid; for by this means the scoriæ are purged away. By repeating this process several times, the iron becomes steel; this method, however, is not often practised, on account of the great loss of weight which the iron undergoes; but the iron becomes the better the less impurity it contains."

Among the Romans the use of iron seems to have been known at an early period of their history. Polybius, the earliest historian of Rome, notices the military use of iron, by which it appears that the helmet and breastplate of the Roman soldiers were of bronze, but the shield had a boss of iron, and an outer border of the same; the sword was a strong cut-and-thrust blade, of Spanish steel, and the spear was pointed with iron. Diodorus Siculus and Pliny the Elder are among the earliest writers on the manufacture of iron. The former mentions Æthalia (Elba), which is even now celebrated, as it was then, for the richness and abundance of its iron ore. Dio-

dorus says, "The natives dig and cut out of the ground the ironstone, to melt, in order for the making of iron; much of which metal is in this sort of stone. The workmen employed first cut the stone in pieces, and then melt them in furnaces built and prepared for the purpose. In these furnaces the stones, by the violent heat of the fire, are melted into several pieces, in form like great sponges, which the merchants buy by truck and exchange of other wares, and export them to Dicæarchea and other mart towns. Some of these merchants that buy of these wares cause them to be wrought by the coppersmiths, who beat and fashion them into all sorts of tools, instruments, and other shapes and fancies; some they neatly beat into the shape of birds, others into spades, hooks, and other sorts of utensils—all of which are transported and carried about into several parts of the world by the merchants."

Pliny, in his Natural History, speaks of iron as "a metal which we may well say is both the best and the worst implement used now in the world; for, with the help of iron, we break up and tear the ground; we plant and plot our groves; we set our port-yards, and range our fruitful trees in rows; we prune our vines, and by cutting off the superfluous branches and dead wood, we make them, every year, to look fresh and young again. By means of iron and steel, we build houses, hew quarries, and cut in stone; yea, in one word, we use it to all other necessary uses of this life.

"Contrariwise, the same iron serveth for wars, murders, and robberies; not only to offend and strike therewith in hand, but also to reach and kill afar off, with divers sort of darts and shot; one whiles discharged and sent out of engines, another while launched and flung by the force of the arm; yea, and sometimes let fly with wings. This I take to be the wickedest invention that ever was devised by the head of man; for, to the end that death may speed away the faster to a man, and surprise him more

suddenly, we make it to fly as a bird in the air, and to the arrow, headed at one end with deadly iron, we set feathers at the other, whereby it is evident that the mischief proceeding from iron is not to be imputed to the nature of it, but to the unhappy wit of man."

The same writer states, that in Calabria, near the sea-shore, there is an entire mountain of iron ore; but the chief seats of the manufacture in Spain, while the Romans possessed the country, were in Celtiberia, which included part of the present provinces of New Castile, and Aragon. The town of Bilbilis seems to have been in the centre of the forges, and the river Salo, which falls into the Ebro, was celebrated for giving a high temper to steel, on account of the coldness of its waters.

Pliny enumerates different qualities of iron, and esteems Seric iron (from the remote east) as the best of all. Next in goodness is the Parthian iron, and next to that is the iron of Noricum (Styria). The magnet stone is found in Calabria. "Iron is the only metal which receiveth strength from that stone; yea, and keepeth the same a long time, insomuch, as by virtue thereof, if it be once well touched and rubbed withal, it is able to take hold of other pieces of iron; and thus, otherwhiles, we may see a number of rings hanging together in manner of a chain, notwithstanding they be not linked and enclosed one within another."

Although iron was so well known to the Romans, yet it appears by the evidence afforded by the excavations of Pompeii and Herculaneum, that articles of bronze were in general use in the middle of the first century, when these cities were overwhelmed by a great eruption of Vesuvius. "It is true, that iron instruments may have been destroyed by rust, during their long sepulture of near seventeen centuries; but, if such ever existed, the wonder and difficulty still remain how bronze and iron should ever be considered as equally applicable

to the same uses. In all the Latin writers, *ferrum*, iron, is the most common name for a sword, but the swords which have been found in these towns are of bronze, as also are the points of spears. Poll-axes and other sacrificing instruments have been found of the same material: even surgeons' instruments, forty in number, some with cutting edges, and all of bronze, were discovered."

The earliest method of smelting iron ore seems to have been in furnaces erected on the summits of hills for the sake of currents of air. The furnaces were perforated on all sides with holes, through which the air was driven when the wind blew. Mungo Park, in his Travels in Africa, describes one of these furnaces, which is supposed to have been constructed on the ancient model. During his stay at Kamalia the smelting furnace was at a short distance from the hut where he lodged. It was a circular tower of clay, about ten feet in height and three feet in diameter, surrounded in two places with withes to prevent the clay from falling to pieces by the heat. Round the lower part, on a level with the ground, (but not so low as the bottom of the furnace, which was somewhat concave,) were seven openings, into each of which were placed three tubes of clay, and the openings again plastered up in such a manner that no air could enter the furnace but through the tubes, by the opening and shutting of which the fire was regulated.

The ironstone he describes as being very heavy, and of a dull red colour with greyish specks; it was broken into pieces about the size of a hen's egg. A bundle of dry wood was first put into the furnace, and covered with a considerable quantity of charcoal; over this was laid a stratum of ironstone, and then another of charcoal, and so on until the furnace was quite full. The fire was applied through one of the tubes, and blown for some time through bellows made of goats' skins. The operation went

on very slowly at first, and it was some hours before the flame appeared above the furnace; but after this it burnt with great violence all the first night; and the people who attended it put in at times more charcoal. The next day the fire was not so fierce, and on the second night some of the tubes were withdrawn, and the air allowed to have freer access to the furnace; but the heat was still very great, and a bluish flame rose some feet above the top of the furnace. On the third day all the tubes were taken out, the ends of many of them being vitrified by the heat; but the metal was not removed until some days afterwards, when the whole was perfectly cool. Part of the furnace was then taken down, and the iron appeared in the form of a large irregular mass, with pieces of charcoal adhering to it. It was sonorous; and when any portion was broken off, the *fracture exhibited a granular appearance like broken steel.*

The owner stated that many parts of this cake were useless, but still there was enough of good metal to repay him for his trouble. This iron, or rather steel, is formed into various instruments, by being repeatedly heated in a forge, the heat of which is urged by a pair of double bellows, of a very simple construction, being made of two goats' skins, the tubes from which unite before they enter the forge, and supply a constant and very regular blast. The hammer, forceps, and anvil were all very simple, and the workmanship (particularly in the formation of knives and spoons) was not destitute of merit. The iron was hard and brittle, requiring much labour in the working.

The following remarks afford a very good commentary on the above description:—

"The practice of these air bloomeries must have been slow in the extreme. A long and continued cementation of the ore in contact with the fuel, must in the first instance have been necessary to

dispose the metallic particles to unite. A too rapid exposure to a high temperature would be apt to unite a considerable portion of oxygen with the ore, which in this way would acquire a considerable degree of fusibility: this would not only diminish the quantity and quality of the iron, but retard the general operation. To render the quality of the iron homogeneous, masses of iron ore would be used as nearly of one size as possible, which would give rise to a rejection, in part, of the small or dust ore, generally the richest of the vein. That this practice prevailed to a considerable extent in Gloucestershire is evident from the large quantities of small mine* found from time to time in the old caverns or weeldons of the mountain limestone formation. These acknowledged evils undoubtedly affected the economy and prosperity of the trade, until some more fortunate or more ingenious worker applied the bellows to the art of iron making, which gave rise to the blast blowing, and occasioned a great revolution and improvement in the fabrication of that valuable and highly useful metal."†

A furnace similar to the above was probably used by the ancient Britons at a very early period. Some historians suppose that the Britons obtained their knowledge of the art of smelting iron during their intercourse with the Phenicians, who traded with them for tin. This intercourse appears to have lasted about 300 years, when it was interfered with by the Greeks about 330 B.C. The tin ingots were conveyed from Cornwall to the Isle of Wight, and sold to the foreign merchants who resorted there.

Diodorus Siculus, speaking of the Britons of the Land's End, Cornwall, says that "they live in a very hospitable and polite manner, which is owing to their great intercourse with foreign merchants." Cæsar also states that, before his time, the trade of

* The ore is commonly called *mine* by the workmen.

† MUSHET, *Papers on Iron and Steel.*

Britain, being carried on by the Gauls, the greatest number of ships from the continent came to the Kentish ports, whose inhabitants were the most polite and conversant with foreign merchants. Strabo mentions iron as one of the exports of Britain. So that it seems tolerably clear that, prior to the Roman invasion, the Britons had discovered or been taught the art of working iron. That such was the case is further proved by the vigorous resistance offered by the Britons to their Roman invaders. Their war-chariots were armed with scythes and hooks, and their cavalry were furnished with broadswords and spears.

When once the Roman conquest was secure, the arts were carried on to an extent before unknown in the island. After the arrival of Adrian (A.D. 120), the *fabrica* or great military forge was established at Bath; and similar establishments were formed in different parts of the country. "Bath would be a spot of all others calculated for such an edifice; contiguous to the hills of Monmouthshire and Gloucestershire, where iron ore was found in the utmost plenty, and centrical in situation for the distribution of the arms which were made at its furnaces, to every part of the kingdom." *

The successors of Adrian continued to work the iron mines till the final abandonment of Britain by the Romans about A.D. 409. Immense beds of iron cinders, left by the Romans, have been discovered in the forest of Dean in Monmouthshire, in Yorkshire, and other counties, among which have been found Roman coins, and the remains of altars inscribed to the god who presided over iron. Many of these heaps are also called *Danes' cinders*, from the idea, probably a correct one, that during the occupation of England by the Danes, the smelting of iron was carried on largely by that people. From the rude method of smelting in these early times, a portion

* SCRIVENOR, *History of the Iron Trade.* 1841.

only of the ore was reduced, and it has been found profitable, in modern times, to smelt these cinders over again. For nearly 200 years the blast furnaces in the Dean forest used nearly one half of the furnace burden of these slags or cinders, which were found highly advantageous to mix with the calcareous ores of the district.*

Scarcely any mention is made of iron in the interval between the Saxon and the Norman conquest. The Anglo-Saxons bestowed especial honour on artificers who excelled in fabricating swords, arms, and defensive armour, all persons being required by law to have arms. According to Camden, the chief trade of the city of Gloucester before and at the time of the Norman conquest, was the forging of iron; and it is mentioned in Doomsday-book, that scarcely any other tribute was required from that city, than thirty-six dicars† of iron, and 100 iron rods, for nails or bolts, for the use of the royal navy. Gloucester was supplied with iron from the forest of Dean.

From the conquest to the death of John, iron and steel were imported from Germany and other countries; the "German merchants of the steel yard" probably deriving that title from the article imported by them, and sold at a place called "The Steel Yard." The art of making defensive armour was, during this period, carried to great perfection, and a smith or armourer was considered a necessary appendage to the establishment of every knight.

During all this time, the fuel used in smelting iron was wood-charcoal, the use of coal coke being unknown. Hence the iron mines were all situated in the wooded districts of England. Iron mines were almost unknown in the north of England, and the metal was of course very scarce, and highly prized. In a predatory expedition made by the Scots in the

* MUSHET.

† A dicar contained ten bars.

tenth year of Edward II.'s reign, no iron was found worth seizing until they came to Furness in Lancashire, where they discovered a quantity manufactured, which they preferred to all other plunder. In consequence of this scarcity of iron, its exportation was prohibited in the twenty-eighth year of Edward III.

Hitherto all articles of iron were forged, the art of casting not having yet been invented; nor is it easy to determine when castings first came into use. Cannon are mentioned as early as 1327, and are supposed to have been first used in England by Edward III. in his invasion of Scotland. They were first made on the same principle as coopers construct their barrels: "a number of iron bars fitting as close as possible to each other, were arranged round a cylinder of wood, and were then bound together by strong iron hoops, the wood being driven out, there remained an iron pipe which formed the barrel. This mode was superseded by casting the cannon of bronze; and at the end of Queen Elizabeth's reign, it is said, the English first attempted to substitute iron for bronze, being induced thereto by the greater cheapness of the latter material, by its greater strength to resist the explosion, and by its greater infusibility, which secured such pieces of ordnance from running at the touch-hole."

During the fourteenth and fifteenth centuries, England was supplied with various manufactures of iron and steel, by Germany, Prussia, and Spain: but, as the home manufacture had considerably improved, the manufacturers of London and other towns, thinking the competition of foreigners to be a grievance, presented a petition to the House of Commons, in 1483, complaining thereof; whereupon an act was passed, prohibiting the importation of knives, hangers, tailor's shears, scissors, andirons, fire-forks, gridirons, stock-locks, keys, hinges, and garnets, spurs, bits, stirrups, buckler-chains, latten-nails with iron shanks,

buckles for shoes, shears, iron-wire, iron candlesticks, grates, &c.

The great and increasing demand for iron caused the extension of iron works to different parts of the island. Camden states, that "Sussex is full of iron mines everywhere, for the casting of which there are furnaces up and down the country, and abundance of wood is yearly spent; many streams of water are drawn into one channel, and a great deal of meadow ground is turned into pools for the driving of mills by the flushes, which beating with hammers upon the iron, fill the neighbourhood night and day with their noise. But the iron here wrought is not everywhere of the same goodness, and in general more brittle than Spanish iron. It yields, however, no small profit to the proprietors of the mines, who cast cannon and other articles in it." At the time when Camden wrote, Sheffield had become "remarkable, among many other places hereabouts, for blacksmiths, there being much iron digged up in these parts;" and it is curious to mark the ignorance of the inestimable value of the coal and iron formations of Staffordshire, in the following passage from the same writer. Referring to this county, he says:—"The south, which has much pit-coal, and mines of iron, but whether more to their loss or advantage, the natives themselves are the best judges, and so I refer it to them."

The vast consumption of wood by the iron smelters, had occasioned so great a scarcity of that article, that in the first year of Elizabeth's reign an Act was passed by which it was enacted, that no timber of the breadth of one foot square at the stub should be cut down for the purpose of making charcoal for the iron manufacture in any place within fourteen miles of the sea, or of any navigable stream, except in the county of Sussex, in the weald of Kent, and a few other places specified. In 1581 a further Act was passed limiting the erection of iron works, stating as

a reason that "the necessary provision of wood, as well as timber fit for building, and other uses, as also all other fellable timber serving for fuel, doth daily decay and become scant, and will, in time to come, become much more scarce, by reason whereof the prices are grown to be very great and unreasonable." Four years later an Act was passed prohibiting the erection of any new iron works in Surrey, Kent and Sussex, and forbidding the use of timber of the size of one foot square at the stub as fuel at any iron work.

It was not till the scarcity of charcoal had stopped many iron works, that attempts were made to use pit-coal in the smelting furnace. Pit-coal had been wrought at Newcastle, prior to the year 1272, and vast quantities were annually exported to Holland and the Low Countries for the use of the smithy. In England, however, strong prejudices existed against its application to the manufacture of cast or malleable iron, as will be seen by the following details.

Many persons during the reigns of James I. and Charles I. attempted to use coal, but none were successful except Dud Dudley, who states, that "having former knowledge and delight in iron works of my father's when I was but a youth, afterward, at twenty years old, was I fetched from Oxford, then of Baliol College, anno 1619, to look over and manage three iron works of my father's, one furnace, and two forges, in the chase of Pensnet, in Worcestershire; but wood and charcoal growing very scanty, and pit-coals in great quantities abounding near the furnace, and to attempt, by my new invention, the making of iron with pit-coal, assuring myself in my invention, the loss to me could not be greater than others, nor so great, although my success should be fruitless; but I found such success at first trial as animated me; for, at my trial, or blast, I made iron to profit with pit-coal, and found *facere est addere inventioni.* After I had proved by a second

blast and trial the feasibility of making iron with pit-coal, and sea-coal, I found by my new invention the quality to be good and profitable, but the quantity did not exceed above three tons per week, though I doubted not in future to have advanced my invention to make quantity also."

Application was made to James I. for a patent for this invention, which was immediately granted for thirty-one years; but in the year after the date of the patent, Dudley's iron works were destroyed by a great flood, "to the joy of many iron-masters, whose works escaped the flood, and who had often disparaged the author's inventions, because the author sold good iron cheaper than they could afford it, and which induced many of the iron-masters to complain unto King James, averring that the iron was not merchantable. As soon as the author had repaired his works and inventions, to his no small charge, they so far prevailed with King James, that the author was commanded, with all speed possible, to send all sorts of bar-iron up to the town of London, fit for making of muskets and carbines; and the iron being so tried by artists and smiths, that the iron-masters, and ironmongers were all silenced until the twenty-first of King James." In this year all monopolies were put an end to, except the patent just mentioned, which was, however, limited to fourteen years. "After which act the author went on cheerfully, and made annually great store of iron, good, and merchantable, and sold it at 12*l.* per ton. I also made all sorts of cast-iron wares, as brewing-cisterns, pots, mortars, and better and cheaper than any yet were made in these nations with charcoal."

The opposition of the iron-masters at length prevailed, and poor Dudley was turned out of his iron-works; on what ground, however, does not appear, for he says it would be "over long to relate." He then proceeded to Himley furnace, in Staffordshire, where he made much iron with pit-coal; "but

wanting a forge to make it into bars, was constrained for want of stock to sell the pig-iron unto the charcoal iron-masters, who did him much prejudice." After this he erected a large furnace, "twenty-seven feet square, all of stone," at Hascobridge in Staffordshire, where he made seven tons of iron per week, "the greatest quantity of pit-coal iron that ever yet was made in Great Britain. Near which furnace the author discovered many new coal mines, ten yards thick, and iron mine under it, according to other coal works; which coal works being brought unto perfection, the author was by force thrown out of them, and the bellows of his new furnace and invention, by riotous persons, cut in pieces, to his no small prejudice, and loss of his invention of making of iron with pit-coal, &c.; so that being, with law-suits and riots, wearied and disabled to prosecute his art and invention at present, even until the first patent was extinct."

The subsequent history of Dudley is but a further illustration of the fate common to first inventors of a useful process or machine; he lost most of his property, and was imprisoned for debt. While he was thus engaged in law, the country was distracted by civil war; his claims were forgotten, and his voice was too weak to be heard in the general confusion; but he had the mortification of witnessing the grant of a patent by Cromwell to one Captain Buck, for making iron with pit coal; and he states that Cromwell and many of his officers were partners in the scheme. The plan, however, proved a total failure. At the Restoration, Dudley presented a memorial to Charles II., which is exceedingly interesting, and contains a clear and masterly epitome of the state of the iron trade at the time, and also of the attempts to make iron with pit coal. We can only find space for one extract from this document.

"God of his infinite goodness—if we will but take notice of his goodness unto this nation—hath

made this country a very cranati, for the supplying these men with iron, coal, and lime, made with coal, which hath much supplied the men with corn also of late; and from these men, a great part not only of this island, but also of His Majesty's other kingdoms and territories, with iron wares, have their supply; and wood in these parts almost exhausted, although it were of late a mighty woodland country. Now, if the coals and ironstone so abounding were made right use of, we need not want iron as we do, for very many measures of ironstone are placed together under the great ten yards thickness of coal, and upon another thickness of coal, two yards thick, not yet mentioned, called the bottom coal or heather coal, as if God had decreed the time when and how these smiths should be supplied, and this island also, with iron; and most especially, that this coal and ironstone should give the first and last occasion for the invention of making iron with pit-coal, no place being so fit for the invention to be perfected in, as this country, for the general good; whose lands did formerly abound in forests, chases, parks, and woods, but exhausted in these parts."

Dudley does not seem to have succeeded in his application, and with one exception, the attempt to produce iron in large quantity was gradually forgotten. The failure does not seem to have arisen from an ignorance of the art of converting coal into coke, for Dr. Plot, in his History of Staffordshire, (published 1686,) says:—"They have a way of charring the coal, in all particulars, the same as they do wood, whence the coal is freed from noxious steams, &c. The coal thus prepared, they call *cokes*, which conceives as strong a heat almost as charcoal itself, and is as fit for most other uses; but for melting, fining, and refining of iron, which it cannot be brought to do, though attempted by the most skilful and curious artists."

It was not till the early part of the next century

that attempts to substitute pit-coal for charcoal were renewed. In 1713, Mr. Darby, of Colebrooke Dale, was the first to use pit-coal; but the progress of the manufacture must have been slow, for in the Philosophical Transactions, for 1747, it is stated as a sort of curiosity, that "Mr. Ford, from iron ore and coal, both got in the same dale, makes iron brittle or tough as he pleases; there being cannon thus cast, so soft, as to bear turning like wrought iron."

The method of using the new fuel was many years in becoming generally known, during which, the quantity of iron produced became less and less, while the demand for it was every year increasing. Immense supplies were obtained from Russia and Sweden, and it was not until machinery became greatly improved, and the steam engine had imparted an almost irresistible strength to the arm of man, that the immense beds of coal and iron-stone were made to operate upon each other in the production of iron.

While this change in fuel was operating, the manufacture became reduced to a very languid state, so much so, that by the year 1740, the number of furnaces had decreased to fifty-nine, being only three-fourths of their previous number; and their annual produce had fallen to 17,350 tons. This, however, was the lowest point of degradation, for as soon as the method of using coke instead of wood was understood, the manufacture revived; so that in 1788, the number of tons of pig-iron produced amounted to 61,300 tons; in 1796, the quantity was increased to 108,793 tons; in 1806, to 250,000 tons; in 1820, 380,000 tons; in 1827, to 654,500 tons; and in 1845, the annual quantity was estimated at 1,250,000 tons.

By noticing the increasing quantity of iron produced by one furnace under the above dates, we obtain a striking illustration of the extent of the demand, and the vast improvements effected in the manufacture.

	Annually Tons.	Cwt.	Qrs.	Weekly Tons.	Cwt.	Qrs.
In 1740, the average produce of each furnace was	294	1	1	5	13	0
1788,	796	2	0	15	6	0
1796,	1046	0	0	20	2	0
1827,	2460	0	0	47	6	0
1845, estimated	5200	0	0	100	0	0

Thus in England alone, during little more than a century, the produce of iron has increased from seventeen thousand to a million and a quarter tons; and the yield of each furnace during the same period has been multiplied nearly twenty fold.

The change in fuel also naturally affected the locality of the manufacture. In 1740, Gloucester produced a much larger quantity of iron than any other county in Britain. Sussex had the greatest number of furnaces; there were a few in Kent, and a few in the midland counties and along the Welsh borders. After the introduction of coke, the coal counties began to assume that rank in connexion with iron, which for so many ages had belonged to the woodland districts. Shropshire, Staffordshire, and South Wales rose into importance, and for some years past the greatest quantity of iron has been produced in South Wales; while in point of skill in the production of a superior metal, Shropshire and Staffordshire have attained the highest excellence.

Thus "in whatever point of view the iron trade may be considered with regard to this country, the advantages derived from its progress have been great: whether we consider it as having cleared the country of vast tracts of wood—affording at the same time an ample indemnification for the labour bestowed—the consequent improvement of climate, and the spread of agriculture; as having placed us at the head of the manufacturing countries of Europe; as affording us at all times a plentiful supply for the construction of every species of machinery; or, as

having been a source of wealth to many individuals, and at the same time, affording a competent recompense for the labour of a number of our fellow-creatures."*

DISTRIBUTION OF IRON ORES—MINING OPERATIONS.

THE profusion with which iron is scattered over the earth has been already alluded to. Its ores are very numerous, but not equally adapted to the purposes of the manufacture; for in some specimens the quantity of metal is too small for profitable working, while in others it is combined with substances which would injure the quality of the iron. All the ores at present used in the manufacture fall under two great divisions: the one including ores in which the iron is united with oxygen, and containing scarcely any other substance; and the other comprising those in which the oxide of iron is in union with carbonic acid, and is mixed with clay, lime, and other earths. Belonging to the first class is the *magnetic iron ore,* found chiefly in primitive countries; it is very abundant at Roslagen, in Sweden, where it is manufactured into a bar-iron, of great value in making steel. A second variety of native oxide of iron is called *iron glance, specular,* and *micaceous iron ore.* The beautiful iron ore of Elba belongs to this variety. A third variety is the *Hœmatite,* or *red ironstone,* which is abundant near Ulverstone, in Lancashire, and is much used in making iron for iron plate and wire. The second division is the source from which by far the greatest quantity of iron is obtained, not that the ores are by any means so rich in metal as those first noticed, but from the single circumstance of their being associated with the fuel required to smelt

* MUSHET.

them. The *clay ironstone* is the substance from which Staffordshire, Shropshire, Wales, Derbyshire, and Scotland, produce such enormous quantities of iron; and not only are these districts furnished with abundance of iron ore and coal, but, generally, at no great distance there is the limestone for fluxing the ore, sandstone for building, and refractory fire clays for the furnaces.

The ironstone usually occurs in horizontal strata, subject, however, to the same inclination as the other strata which it accompanies. It is generally found imbedded in schistus clay, more or less compact, which moulders away when exposed to the air. The ironstone is met with under two different forms; in regularly connected strata called *bands*, and in strata of detached stone, formed in distinct masses, from the size of a small bullet to that of lumps of several hundred pounds weight. Small and middling-sized stones, and which generally have a flat ovular form, are called *ball stones;* those of great weight are named *lunkers*. In Staffordshire, a variety of local names are applied to the ironstone: when found in beds or seams, the miners call it *blue flats, blue clist,* and *whitestone;* when it is found in balls or lumps, imbedded in clay, the different qualities are expressed in terms which will convey little or no meaning to the reader, such as *clunch, binds, ironstone-bearer, penny-earth, gubbin-stone, poor robin,* &c.

When the ironstone occurs near the surface, all that is necessary to procure it is, to remove the soil and earth; the stone then presents itself like a pavement, more or less inclined. It is easily raised by the application of wedges, bars, &c., but as all secondary strata descend, the stone of course becomes gradually buried under an accumulating depth of earth, which is more and more expensive to remove. Horizontal galleries are then perforated under the soil, to the extent of from 100 to 240 yards, so as to fall in with the declivity of the strata. In Scotland,

these galleries are called the *barrow roads.* When the miner has arrived at the end of one of these galleries, he turns round and commences an excavation on his right and left hand, proportioned to the rise and dip of the stone, to the extent of several yards on each side; the accompanying shale and rubbish are packed into the vacant space behind him, or it is wheeled to the mouth of the gallery along with the ironstone. In this way the miner clears out the whole ironstone contained in 100 to 240 yards in the length, and in 20 to 30 yards in width. The thickness of the band may not exceed four inches, but, if of good quality, this is quite sufficient to pay the expenses of working. The height of the gallery is commonly so small, that the miner is obliged to perform his work lying upon his side; the wheelers are likewise obliged to push the barrow on all fours. These galleries are cooler than coal mines at the same level; but they are also more wet and dirty. The chief danger to which the miner is exposed arises from the occasional falling in of a portion of the roof; there is little or no danger from noxious gases, such as occur in coal mines.

When the galleries have been carried on for a certain length, the expense of wheeling out the stone becomes too great: a more economical method is therefore adopted. A pit is sunk at a spot from 160 to 200 yards farther on the same line of level, and when the ironstone is found, the miner sets off another gallery or barrow road towards his former working, and continues till he meets the termination of his old waste: then, as before, he returns, carrying off a similar portion of ironstone from each side of the gallery. The other side of the pit is next perforated, and when all the ironstone is obtained, another pit is sunk at a similar distance from the termination of the second gallery in the first, and this opens a new field of supply. This process is repeated until the field is totally exhausted.

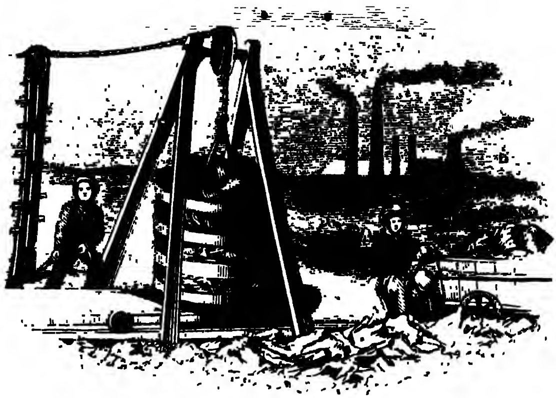
These extensive excavations commonly collect a considerable quantity of water, which is removed in various ways, such as running a counter gallery as near to the declivity of the metals as possible, and passing the water into it; or the water is extracted from one general reservoir by means of pumps worked either by water wheels or the steam engine.

When the ground is tolerably level, and the ironstone is at some depth, a pit is sunk at once from the surface. Galleries are run from this pit at different depths, for the purpose of working both the coal and the ironstone. In a pit near Wolverhampton, visited by the writer, the galleries were of sufficient height to allow a horse to work in them. The iron-

COAL AND IRON PIT

stone was loaded in small carriages, moving upon a rail road, and drawn by the horse to the mouth of the pit. Here a sort of circular platform was loaded with the stone to a considerable height; the mass being supported by loose, flexible bands of iron. When drawn up to the top, a platform was wheeled over the mouth, upon which the load was rested while being unpacked. The ironstone is spread over the surface of the ground, in a heap two or three feet high, preparatory to its being roasted. The appearance of an iron district which has been extensively excavated, is sometimes not a little curious:

portions of the ground give way; houses assume



THE MOUTH OF PIT

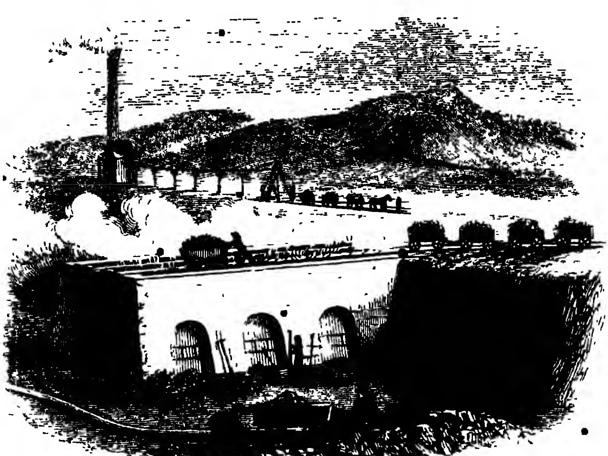
various inclinations; walls crack and totter, and are only prevented from falling by huge unsightly but-

EFFECTS OF MINING

tresses. The preceding cut is from a sketch taken in Colebrooke Dale, situated on the upper course of the Severn, in the county of Shropshire. The Dale is enclosed by limestone rocks, covered by a succession of richly wooded knolls, presenting a succession of pictures, whose beauty is much obscured by smoke, and their tranquillity interrupted by the sound of the hammer and the roar of the furnace. At night-fall, the appearance of the Dale is peculiarly striking, being lit up by the flames of the blast furnaces of Horse Hey and Dawley, dissipating the darkness for miles around, by a flickering, uncertain light, which is painful to the eye, and destructive of the repose which belongs to the night season.

ROASTING THE ORE.

THE first operation in the manufacture of iron is roasting the ore, which is done in kilns or furnaces, or in large heaps in the open air. When fur-



ROASTING THE IRONSTONE IN KILNS.

naces are employed, they are filled entirely with ironstone, except a stratum of coals in the bottom, the combustion of which produces the effect required. After the ironstone is sufficiently burnt, the register is shut up, the fire goes out, and when the furnace is cool enough, the ore is removed to the smelting house.

The more common method, however, is to roast the ironstone in heaps, for which purpose a piece of ground is levelled, and covered with a layer of small pit coal, four, six, or eight inches thick. The pieces

ROASTING THE IRONSTONE IN HEAPS.

of ironstone, as near the same size as possible, are imbedded upon this to the height of from eighteen to twenty-four inches. This surface is again levelled by introducing small pieces of ironstone in the spaces left by the larger pieces. Upon this small coals are again cast, to the depth of two inches. Ironstone is then piled up, gradually narrowing to a wedge-shaped heap, and then the whole is covered over with small coal. The pile is lighted by applying burning coals to the ground stratum. The fire creeps slowly along,

gradually inflaming the whole heap from the bottom to the top. When the coals are all burnt out, the pile gradually cools, and in eight or ten days it is fit for the furnace.

COKING THE COAL.

In cold blast furnaces, or those in which cold air is used to excite combustion, the coal used in the reduction of the ironstone has to be converted into coke. Coking is performed upon a flat oblong or circular surface called a *hearth:* this is prepared by beating it firmly, and puddling it over with clay. The coal is arranged on the hearth in pieces regularly inclining to each other, care being taken to place each piece on its sharpest angle, so that the smallest possible surface may touch the ground. By this means spaces are preserved for the admission of air necessary to ignite the coal, and room is left for the swelling of the various masses. In building the pile a number of vent holes are left, extending from the top to the bottom. In first igniting the heap, burning fuel is put into these vents, which are then stopped by small pieces of coal, to prevent the fire from ascending, and to force it to seek a passage by creeping along the bottom, where there is the freest access of air. When the fires of the different vents meet, the combustion gradually rises and bursts forth on all sides. Soon after the smoke has ceased, the fire is covered up with the dust and ashes of former burnings, beginning at the base, and gradually heaping it up to the top.

The quantity of coals coked in one hearth varies from forty to eighty or a hundred tons. The time required to produce good coke depends on the kind of coal used, and the state of the weather. The combustion may be complete, and the heap completely covered over, in from fifty to seventy hours; but it will not be cool enough for drawing under

twelve or fourteen days. There is an enormous loss of weight in converting coal into coke. Mr. Mushet found that—

2,240 lbs. of free coals	yield 700 lbs. of coke,	making a loss of 1540 lbs.
2,240 lbs. of splint and free coal, mixed	yield 840 lbs. of coke,	making a loss of 1,400 lbs
2,240 lbs. of splint, " slightly mixed	yield 1,000 lbs. of coke,	making a loss of 1,240 lbs
2,240 lbs. of pure splint	yield 1,100 lbs. of coke,	making a loss of 1,140 lbs.

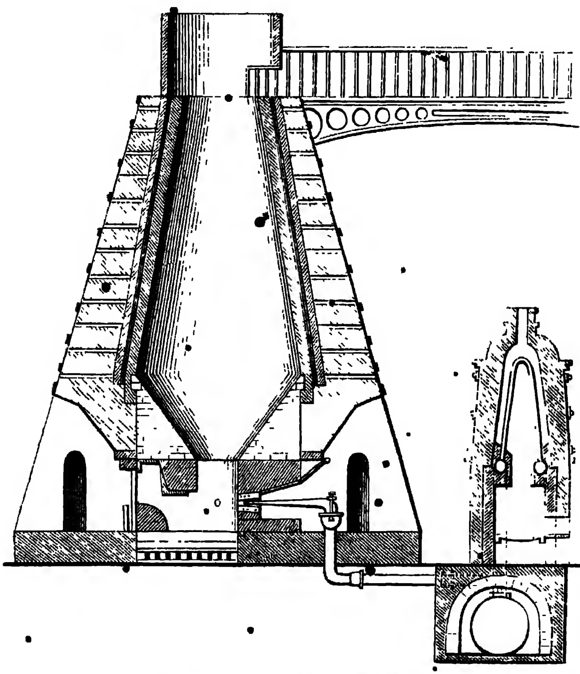
The appearance which all these coking fires give to an iron district by night is very striking; and in Wales, where the heaps are extended to a considerable length, the spectacle is described as being grand and imposing. "The long rows of flame produced by the burning of many hundred tons of coal, extending over a vast space of ground, and flickering in the wind; the black, grotesque figures of the cokers brandishing their long rakes, and partially visible through the thick lurid smoke, with the roaring of the blast and the noise of machinery, seem to realize the descriptions of Virgil or Dante rather than any thing familiar to our experience in this habitable world."

SMELTING.

The ironstone, coke, and flux, being properly prepared, are brought to the blast furnace, which is the most important feature in an iron work, rising as it does to the height of from fifty to seventy feet, and lighting up the country around like a small volcano.

The external form of the smelting furnace is that of a truncated-pyramid; it is built of strong masonry, with contrivances to prevent cracking by the expansion which takes place when it is brought to the state of intense heat necessary to smelt the ore. The interior of the furnace consists of five parts, which,

reckoning from the bottom upwards, are as follows:—1. The *hearth*, which is composed of a single block of quartz-grit about two feet square. 2. Upon this is erected what is sometimes called the *crucible*, which is a four-sided cavity six feet and a half high, slightly enlarging upwards, so as to be two feet and a half square at the top. 3. The part above this, called the *boshes*, is in the form of a funnel or inverted cone, eight feet in perpendicular height, and twelve feet in diameter at the top; this is the widest part of the

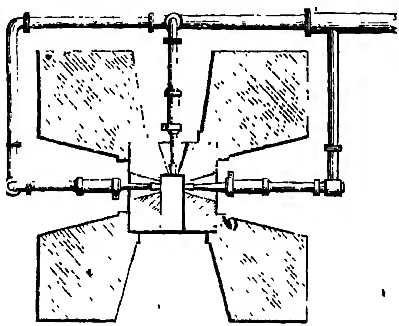


SECTION OF HOT BLAST FURNACE

interior, and terminates (4.) the *cavity* of the furnace, which is conical in shape, and extends upwards to the height of thirty feet, the diameter at the top not

being more than three feet: here it again enlarges into (5.) the *chimney*, which is about eight feet high and sixteen in diameter at its mouth. This form at the upper part has been modified since the introduction of the hot blast, that given in the section being preferred.

About two feet above the hearth three openings are made in the sides of the crucible to admit the extremity of the blast pipes, through which air is forced into the furnace, and at the bottom of the



ARRANGEMENT OF TUYERES.

crucible are openings through which the scoriæ and melted metal are from time to time discharged.

The cavity of the furnace receives a double lining of fire-bricks made expressly for the purpose. A space three inches broad is left between the two linings, which is filled with moist loamy sand. This space is allowed for any expansion which might take place in consequence of the swelling of the materials when the furnace is at work.

The above are the dimensions of a moderately sized furnace. The largest furnaces probably in the world are those of South Wales, the diameter at the boshes or widest part being in some cases from 15 to 18 feet, and having a capacity equal to 7000 cubical feet. Such a furnace when at work will contain at least 150 tons of ignited materials. In

Staffordshire, Shropshire, and other parts of England, a furnace seldom exceeds 13 or 14 feet diameter at the boshes.

When a new furnace has been erected, considerable care is required in raising it to the temperature necessary for smelting iron. A temporary fire-place is first erected at the lower part, to which the whole cavity of the furnace is made to act as a chimney; so that when the fire is lighted the draught is violent, and much heat is carried up. This fire is kept burning for about three weeks, at the end of which time the furnace is sufficiently dry to receive a charge of coke; the temporary fire-place is removed, and other preparations made for the purpose. A quantity of ignited coke is thrown in, and this is gradually increased until the whole cavity is filled. The quantity required by a furnace of the dimensions given above will be about 99,000 lbs.; the splint coal for which would weigh 198,000 lbs. "When we reflect," says Mr. Mushet, "that this vast body of ignited matter is replaced every third day when the furnace is properly at work, a notion may be formed of the immense quantity of materials required, as also the consequent industry exerted to supply one or more furnaces for the space of one year."

All the materials are conveyed in wheel-barrows, and thrown into the furnace at its mouth or chimney. Where there is a regular incline from the coke-yard or kilns to the furnaces, the loaded barrow is wheeled directly to the furnace top; but in a flat country the barrows are arranged on stages, which are supported in a horizontal position, and drawn up an inclined plane as shown in the annexed cut, which represents some furnaces near Hanley, in Staffordshire, which were visited by the writer. At the top of the inclined plane is a gallery sufficiently wide for wheeling the barrows round to the three mouths with which each furnace is provided, and into these a man called the *filler* throws the contents of each barrow.

At the furnaces at Horse Hey there is a regular ascent from the coke-yard to the mouths of the furnace, and small carriages moving on a railroad bring up constant supplies of coke or coal, ironstone and

BLAST FURNACES.

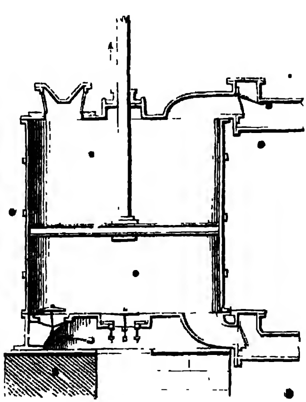
limestone, which are weighed in certain proportions and conveyed in barrows to the mouths of the furnaces, as shown in the following cut.

When the furnace has been sufficiently heated by coke, proportionate *charges* of coke, ironstone, and blast furnace cinders are added. At first the ironstone bears only a small proportion to the weight of the coke, but this is afterwards increased to the full burden. The filling is continued regularly, and when the top of the furnace has acquired a considerable degree of heat, the blast is introduced.

The blowing machines vary considerably in construction at different works; a very common arrangement is to have a cylinder at the end of the beam of a steam-engine of twenty or thirty horse-power, closed at both ends, with a piston moving throughout its length. Towards the top and bottom of this cylinder

MOUTHS OF BLAST FURNACES.

are orifices covered with valves, opening inside, and closing by their own weight. When the piston is moving downwards and expelling the air below it out of the cylinder, a fresh supply of air rushes in

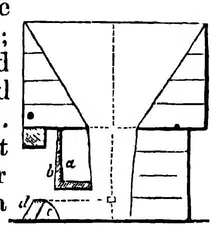


SECTION OF BLOWING APPARATUS

through the upper valve, so that by the time the piston is ready to make its up-stroke the cylinder is again filled. During the up-stroke all the air above the piston is expelled, and the lower valve opens, and air rushes in to fill the cylinder below the piston. It is evident, however, that this action would not produce a regular blast: the air is, therefore, received into a large metal box or globe, and the elasticity which it here acquires by compression causes it to issue in a nearly equable stream. This vessel is furnished with a safety valve, by which the pressure of the air is regulated, the pressure being made to vary according to the nature of the fuel and the season of the year. In summer, when it is more rare, it is expelled under greater pressure. The limits are from $1\frac{1}{2}$ lbs. to $3\frac{1}{2}$ lbs. on the inch, in addition to the average pressure of the air, which is $14\frac{3}{4}$ lbs. on the square inch of surface. The orifices, or nose pipes, through which the air issues, also vary with the nature of the coke and the ore, from $2\frac{5}{10}$ to $2\frac{9}{10}$ inches in diameter.

We are so much accustomed to consider air as having little or no weight, that the fact may perhaps excite surprise that the weight of the air sent into the furnace in the twenty-four hours is at least four times as much as that of the charge. In a cold-blast furnace near Glasgow a few years ago, the volume of air thrown in, when reduced to atmospheric pressure, was estimated at 6,292 cubic feet per minute, the weight of which in 24 hours would be 6,192 *hundred weight*, while the whole weight of the charges of coke, ore, and limestone during the same period was no more than $666\frac{1}{2}$ *cwt.*, so that in this case the weight of air was more than nine times and a quarter that of the charges. This, however, was an extraordinary case; but by another calculation it appears, that an ordinary cold-blast furnace consumes as much air as is required for the respiration of 200,000 persons.

As we are tracing the operations for a new furnace, it is necessary here to remark, that before admitting the blast certain preparations are necessary. The dam-stone *c* is laid in its place and firmly imbedded in fire clay; the dam-plate *d* is again imbedded on this with the same cement, and the same inclination is given to it. On the top of this plate is a slight depression curved outwards, for allowing the scoria to flow off in a connected stream as it tends to surmount the level of the dam. From this notch to the level of the floor, a declivity of brick work is erected, down which the scoria flows. The opening between the dam and the side walls of the furnace, called the *fauld*, is stopped up with sand, and the furnace bottom is covered with powdered lime or charcoal dust. Ignited coke is then allowed to fall down, and is brought forward with iron bars nearly to a level with the dam. The tuyere hole is opened and lined with a soft mixture of fire clay and loam. The blast is first introduced through a small discharge pipe, which is afterwards increased in size. In about two hours after blowing, a considerable quantity of lava will be accumulated, which is admitted to all parts of the hearth, and soon thoroughly heats and glazes the surfaces of the fire-stone. It then rises to a level with the notch in the dam-plate, and flows over. When the metal has risen nearly to a level with the dam, it is let out by cutting away the hardened loam of the fauld, and conveyed by a channel made in sand in front of the furnace to its proper destination, which will be further noticed presently.



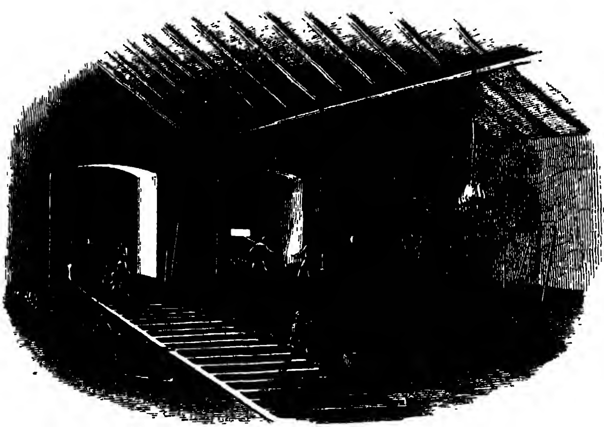
In six days from the commencement of blowing, the furnace will have wrought itself clear, and will have acquired capacity sufficient to contain from 5,000 to 7,000 lbs. weight of iron. At this period the charge will be in the following proportions:—400 lbs.

of coke, 336 lbs. of ironstone, and 100 lbs. of limestone. This charge is thrown into the furnace every hour.

The action of the coke, ironstone, and limestone upon each other in the furnace is somewhat complicated, and it may perhaps be sufficient to state that they ultimately form at the bottom of the furnace two liquid products, one of which is a glass composed of the limestone in combination with the earthy impurities of the ore, which when drawn off and left to cool forms solid *scoriæ*, *slag* or *cinder*; and the other a compound of the carbon of the fuel and the metal, forming a carburet of iron. As the materials gradually descend from the top to the bottom of the furnace, the ore is undergoing cementation during several hours in contact with the burning fuel, and is almost saturated with carbon when it reaches the bottom of the boshes, or hottest part of the furnace. Here it is that the limestone-flux and the earthy impurities of the coke and ore run down into a slag; the iron also is melted, loses a portion of its carbon, and acquires oxygen from the blast. The fluid mass soon sinks to the bottom of the furnace beyond the influence of the blast, the iron being the heaviest occupies the lowest place, and the covering of scoriæ protects it from further loss of carbon. As the melted matter accumulates, the slag is allowed to flow out, as before noticed, and the iron is drawn off at intervals every eight or twelve hours, according to circumstances. This work is continued with double sets of attendants, day and night without intermission, for two or three years; for if the furnace were allowed to cool, the contents might become solid and the furnace be ruined. The writer, however, has peculiar satisfaction in learning that arrangements have been made at some works for not casting on Sundays, so that nothing more is required than the attendance of a single workman to keep the furnaces supplied with fuel.

Drawing off the iron, or *casting* as it is called, is a

beautiful and striking spectacle. The shed in front of each furnace is covered with sand to the depth of about ten or twelve inches; previous to each *cast* a channel called the *sow* is formed in the sand, extending some forty or fifty feet from the furnace; branching off from the sow at right angles a number of smaller channels, called *pigs*, are formed by burying a number of bars of wood of the required size, on the removal of which the pig-moulds are left sharp and distinct. The hole in the bottom of the hearth, which was stopped with a mixture of sand and clay,



is tapped, and the molten stream flows out sparkling and bright, the light and heat becoming more and more intense as it rolls on and increases in volume. In order to make the metal flow regularly into the side channels, it is necessary here and there to interrupt the progress of the stream, which is done by a long piece of wood, as the metal does not continue sufficiently fluid to fill them up equally, but by this method the pigs are all perfectly formed. When the

metal is set, the pigs are broken off from the sow, and the latter is also broken to pieces with a large sledge hammer.

Six different kinds of pig iron are distinguished by the manufacturer. The first three, named No. 1, No. 2, and No. 3, are considered as foundry metal; they contain carbon in different degrees, but all of them in a higher degree than those selected for making bar or malleable iron. No. 1 is saturated with carbon, the effect of which is to render the iron soft, and very fluid when melted, so that it will adapt itself perfectly to the shape of the mould, and is hence used for small and ornamental castings. It is also so soft as to yield readily to the chisel. No. 2 contains less carbon than No. 1; it is not so soft when cold, nor so fluid when melted; but, being harder and stronger, is preferred for those parts of machinery which require strength and durability. The quantity of carbon contained in these two sorts renders them unfit for being manufactured into bars; but No. 3, or *dark grey iron*, containing less carbon than No. 1 or No. 2, can be used either for the forge or for the foundry. It is much used for heavy castings, such as tram plates, heavy shafts, wheels, cylinders of steam engines, &c. The next quality is called *bright* iron, from its being of a lighter colour and brighter lustre than the foregoing varieties. It is used for large castings, but is not sufficiently fluid for fine work. A fifth variety is *mottled* iron, the fracture of which is *mottled* with grey and white. It is too thick and brittle for the foundry, and its use is therefore confined to the forge. The last variety is called *white* iron, from its silvery white colour. It is quite unfit for casting, on account of its thickness and extreme brittleness. It contains a smaller proportion of carbon than any other sort of pig iron.

The different kinds of iron present different phenomena in coming out of the furnace, which have been well described by Mr. Mushet. He says :—

"When fine, (No. 1.) or supercarbonated, crude iron is run from the furnace, the stream of metal, as it issues from the fauld, throws off an infinite number of brilliant sparkles of carbon. The surface is covered with a fluid pellicle of carburet of iron [plumbago], which as it flows rears itself up in the most delicate folds. At first the fluid metal appears like a dense ponderous stream, but as the collateral moulds became filled, it exhibits a general rapid motion from the surface of the pigs to the centre of many points; millions of the finest undulations move upon each mould, displaying the greatest nicety and rapidity of movement, conjoined with an uncommonly beautiful variegation of colour, which language is inadequate justly to describe. Such metal in quantity will remain fluid for twenty minutes after it is run from the furnace, and when cold will have its surface covered with the beautiful carburet of iron, already mentioned, of an uncommonly rich and brilliant appearance."

Very different is the appearance of the inferior iron, No. 4, when issuing from the blast furnace. From all parts of the fluid surface, is thrown off a vast number of metallic sparks, arising from a cause different to that exerted in the former instance. The absence of carbon renders the metal subject to the combination of oxygen as soon as it comes into contact with atmospheric air. Small spherules of iron are ejected from all parts of the surface, to the height of two or three feet, when they inflame and separate with a slight hissing explosion into a great many minute particles of brilliant fire. These particles consist of oxide of iron. "The surface of oxygenated iron, when running, is covered with waving flakes of an obscure smoky flame, accompanied with a hissing noise; forming a wonderful contrast with the fine rich covering of plumbago in the other state of the metal, occasionally parting and exhibiting the iron in a state of the greatest appa-

rent purity, agitated in numberless minute fibres, from the abundance of carbon united with the metal."

As the oxygenated iron cools, its upper surface becomes covered with a scale of blue oxide, which being removed, a number of deep pits are presented. "This iron in fusion stands less convex than carbonated iron merely because it is less susceptible of a state of extreme division; and indeed, it seems a principle in all metallic fluids, that they are convex in proportion to the quantity of carbon with which they are saturated." The appearances of No. 2 and No. 3 in a state of fusion present some of the appearances of both No. 1 and No. 4.

The quality of the metal can also be judged of before it is run from the furnace by the colour and form of the scoriæ, the colour of the crust upon the working bars, and the quantity of carburet attached to it. That cinder which indicates the presence of carbonated iron in the hearth of the furnace forms itself into circular compact streams, which become consolidated and inserted into each other; these are in length from three to nine feet. "Their colour, when the iron approaches the first quality, is a beautiful variegation of white and blue enamel, forming a wild profusion of the elements of every known figure; the blues are lighter or darker according to the quantity of the metal and the action of the external air while cooling. When the quality of the pig iron is sparingly carbonated, the blue colour is less vivid, less delicate, and the external surface rougher and more sullied with a mixture of colour." The cinder emitted from the furnace when No. 3 iron is produced, assumes a long zigzag form. "Its tenacity is so great, that if, while fluid, a small iron hook be inserted into it at a certain degree of heat, and then drawn from it with a quick but steady motion, 20 to 80 yards of fine glass thread may be formed with ease. When by accident a quantity of this lava

runs back upon the discharging pipe, it is upon the return of the blast, impelled with such velocity as to be blown into minute delicate fibres, smaller than the most ductile wire. At first they float upon the air like wool, and when at rest, very much resemble that substance."

The cinder frequently crystallizes in cooling: cellular masses form among it, which on being opened are sometimes found full of perfectly crystallized forms.

THE HOT BLAST.

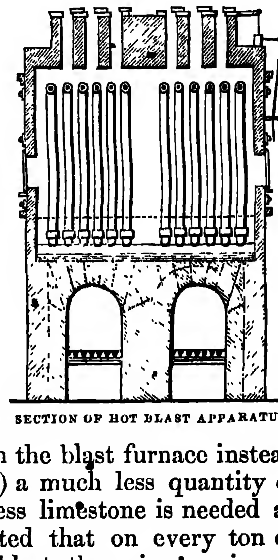
It had long been the opinion of practical men that the colder the blast the better was the iron produced, and this opinion seemed to be confirmed by the fact that blast furnaces did their work better and produced more iron in winter than in summer. Considerable surprise was therefore felt in the year 1828 when the discovery was announced, that by using a *hot* instead of a *cold* blast, a great saving of fuel could be effected, and a much larger quantity of iron produced. This discovery was made by Mr. Neilson, manager of the Glasgow Gas Works, who has himself related the circumstances which led to it.

"In 1824, an ironmaker asked Mr. Neilson if he thought it possible to purify the air blown into blast furnaces, in a manner similar to that in which coal gas is purified; and from this conversation Mr. Neilson perceived that he imagined the presence of sulphur in the air to be the cause of blast furnaces working irregularly, and making bad iron in the summer months. Subsequently to this conversation, which had in some measure directed his thoughts to the subject of blast furnaces, he received information that one of the Muirkirk iron furnaces, situated at a considerable distance from the engines, did not work so well as the others; which led him to conjecture that the friction of the air, in passing along the pipe,

prevented an equal volume of the air getting to the distant furnace, with that which reached to the one situated close by the engine; and he at once came to the conclusion, that by heating the air at the distant furnace, he should increase its volume in the ratio of the known law according to which airs and gases expand. Thus, if 1000 cubic feet, say at 50° Fahr., were pressed by the engine in a given time, and heated to 600° Fahr., it would be increased in volume to 21,044; and so on for every thousand feet that would be blown into the furnace. In prosecuting the experiments which this idea suggested, circumstances however convinced him, that heating the air introduced for supporting combustion into air-furnaces, would materially increase its efficacy in this respect; and with the view of putting his suspicions on this point to the test, he instituted the following experiments:—to the nozzle of a pair of common smith's bellows he attached a cast-iron vessel, heated from beneath in the manner of a retort for generating gas; and to this vessel the blow-pipe by which the forge or furnace was blown was also attached. The air from the bellows having thus to pass through the heated vessel above mentioned, was consequently heated to a high temperature before it entered the forge fire, and the result produced in increasing the heat in the furnace was far beyond his expectation; whilst it made apparent the fallacy of the generally received theory, that the coldness of the air of the atmosphere in the winter months was the cause of the best iron being then produced. But in overthrowing the old theory, he had also established new principles and facts in the process of iron-making, and by the advice and assistance of his friends, he applied for and obtained a patent as the reward of his discovery and improvement."

The method of heating the air was not made the subject of the patent. The air heating vessels first used were in the form of a round, a square, or a

cylindrical box; they were next elongated, and by a further improvement were divided into parts; but the best form, and that which is now generally used, is a congeries of tubes, whereby the greatest extent of heating surface is obtained. The following is a lateral section of the last named apparatus, in which the air can be raised to 600°, the melting point of lead, at which temperature the greatest effect is produced, and is determined by holding a piece of lead over an orifice in the blast pipe.


SECTION OF HOT BLAST APPARATUS.

The hot blast was soon adopted in Scotland, and more slowly in England. The charge made by the patentees for a licence to use the invention was one shilling for each ton of iron produced by it; and it has been calculated that on the expiration of the patent in 1842 the patentees had received no less a sum than 300,000*l.*

The value of the hot blast will be at once appreciated from the following facts, (1) that coal can be used in the blast furnace instead of or mixed with coke, (2) a much less quantity of fuel is required, and (3) less limestone is needed as flux. It has been calculated that on every ton of iron produced by the hot blast, there is a saving of 1*l.* 12*s.* 6*d.*; viz, five tons of coal at 5*s.* 6*d.* per ton; half a ton of limestone at 4*s.* per ton, and 3*s.* saved in wages by not coking the coal.*

The great saving of fuel in the furnace by the use of the hot blast will be understood by considering for a moment the nature of combustion under ordinary circumstances. A combustible body such as

* North British Review, Vol. IV.

paper, wood, coal, and a supporter of combustion, such as the oxygen of the atmosphere, show no tendency to unite at the ordinary temperature of the air; but if either the air or the combustible body be raised to a high temperature, a union between the two takes place with a rapidity proportioned to the temperature and also with the production of heat and light. The air which feeds an ordinary fire must be raised by the burning fuel to the combining temperature before combustion can take place, but if by any contrivance a high temperature be imparted to the air before it reaches the fire, part of the work of the burning fuel is already performed, and it will not only burn longer, but will give out a greater heat, because it has not to expend so much of its force in raising the air necessary to feed it to the proper temperature.

In the blast furnace a great and long sustained heat is necessary to effect the reduction of the iron. Now it must be obvious under the cold blast method, that one portion of the fuel in the furnace is employed in raising the air to the necessary temperature, thereby rendering the other portion less efficient, and tending to depress the temperature of the whole contents of the furnace. Besides this, there is another drawback. When compressed air escapes from pressure, its temperature is many degrees below that of the external air. Mr. Mushet states, as the result of actual experiment, that while the heat of the outer air was from 60° to 70 Fahr. the temperature of the blast as shown by a thermometer held in it, was as low as 38°. It is, therefore, easy to perceive that a very large proportion of the fuel of the furnace must be expended in raising the temperature of the blast to the point of combustion: but by the hot blast the whole of the fuel is effective in doing the proper work of the furnace, in maintaining a higher temperature than could otherwise be produced, and consequently economising the fuel and affording more

iron in less time. Mr. Mushet thinks, that previous to the introduction of the hot blast, nearly one half the quantity of the fuel introduced into the furnace was expended in preparing the air for combustion. By means of the hot blast the air is rapidly and entirely decomposed, "an intense temperature is excited locally, into which the fusing matters precipitate themselves, and where separation is effected under a degree of heat not formerly known to exist in the blast furnace. The whole of the blast being decomposed between the tuyeres and the boshes, the upper part of the furnace becomes converted into a cone of cementation, wherein the important but progressive processes of deoxydation and carbonization are carried on and perfected in the absence of oxygen, and in a more certain state of preparation than is effected under the cold blast system."

Another advantage of the hot blast is that ores previously unfitted for the manufacture of foundry iron can now be smelted. Anthracite or stone coal, which formerly could not be used in the furnace, is now used in the raw state. The pig iron is also of better quality; for with the cold blast it is necessary that a certain quantity of earthy matter be present in the furnace, to form cinder for the protection of the iron, and to prevent the furnace from throwing off black cinder, technically called *scouring*; this is no longer necessary, because the iron when it flows from a hot blast furnace has a much higher temperature than under the cold blast, and it is stated that oxygen does not readily unite with iron at a very high temperature. "That such intense temperature is communicated to the pig iron made with hot blast, is sufficiently obvious at casting time, when the highly convex stream of metal is seen rolling from the furnace, active with external motion, and disparting itself in millions of delicate yet distinct undulations as the current recedes from the furnace to occupy and fill its destined channels in the sand bed. An eye accustomed to view appearances of this sort will at

once, as soon as the iron has left the furnace, perceive a glow upon its surface beyond what is commonly called a white heat, a liquidity, carrying with it a slight tinge of azure."

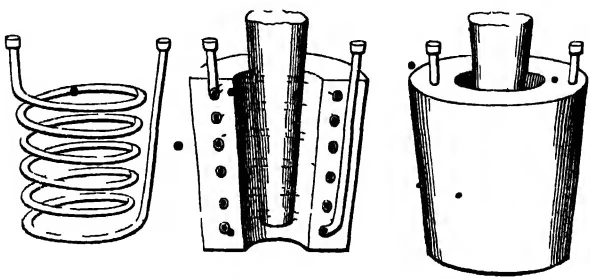
One defect of hot blast iron is said to be a slight deterioration in strength, which arises probably from the high temperature at which it is finally separated from its ores, communicating, by a new and more perfect crystallization, a weaker arrangement of parts. It has also been suggested that silica may be reduced with the ore, and its metallic base, silicon, uniting with the iron, imparts to it a certain amount of brittleness.

The increased quantity of iron produced under the hot blast, produces, of course, an increased quantity of vitreous matter or cinder, which no longer flows in streams forming columns of from three to nine feet in length, but in liquid torrents of from fifteen to twenty feet in length. At some furnaces where a powerful blast is used, accompanied with a proportionate flow of cinder, it is at once run into wagons made of strong sheet iron or boiler plate, and taken away to the cinder tip, over which it is discharged in solid masses, moulded to the shape of the wagon. By this contrivance a great saving of labour is effected, the clearing away of the cinder under the old method being the most laborious part of the attendance on a blast furnace.

The increased heat caused by the use of the hot blast rendered some contrivance necessary to protect the nozzle of the air pipe as it entered the furnace. The following ingenious method was adopted. Within the sides of the iron tuyere through which the nozzle passes, is introduced a spiral pipe, in which a stream of water is constantly playing. The tuyere is thus kept comparatively cool, forming an effectual protection to the nozzle of the air pipe. The first of the following figures shows the form of the spiral tube before being cast into the metal of the tuyere; the second figure is a section of the tuyere or tue-iron,

showing the spiral tubing enclosed in cast iron. The nozzle of the blast pipe is also shown introduced into the tuyere, the surrounding space being afterwards filled with fire clay. The third figure shows the

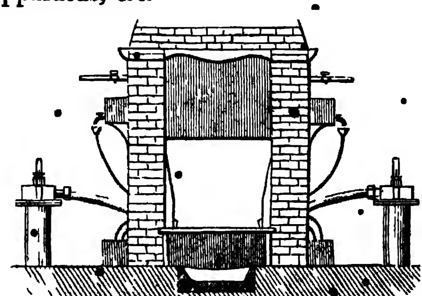
1. 2. 3.



R NOZZLE OF TUYERE

tuyere ready for putting into the furnace. "Without the cooling effects of water circulating with rapidity on the confines of the fire, and frequently penetrating to some distance within it, there is no substance with which we are acquainted that could for any length of time have resisted the action of so intensely heated a body of fire."

The following section shows the arrangement of the lower part of the furnace, with two of the tuyeres, water apparatus, &c.



SECTION OF LOWER PART OF FURNACE.

REFINING.

ALL the varieties of pig iron contain varying proportions of carbon and oxygen, which render them brittle under the hammer, and therefore quite unfit for the numerous purposes of the forge. In order to render pig iron malleable it is necessary to get rid of some of the carbon and oxygen, and the greater the extent to which this is done, the purer and more malleable becomes the metal. For this purpose various interesting processes are adopted, and the first to which we shall direct attention is called *refining*.

Pig iron is refined in small low furnaces called *fineries*. The bottom of the hearth of a finery is about three feet square, and is made of fire-brick; the front, back, and sides, are of cast iron, and made hollow, so as to allow water to stream through them, to prevent the intense heat of the fire from burning them away. Near the top of the hearth are three holes for the blast pipes. In what are called *single fires* the blast is applied on one side only; in *double fires* on both sides, the latter being of much larger capacity than the former. The tuyeres are protected in a similar manner to those in the blast furnace. The finery has iron doors at the back, but the front is open, and pours forth such torrents of heat that it is impossible for any but those accustomed to it to approach very near. A low chimney surmounts the furnace, which altogether does not exceed about twenty feet in height. In front of the fire is a shed for the protection of the workman. The refiner selects his materials according to the quality of the iron required, the best quality being made from the dark grey pig, No. 3, and inferior sorts from bright, mottled, and white. The proper weight of pigs is put into the refinery by opening the iron doors at the back, and the fire is kept well supplied with coke, and frequently stirred up to equalize the heat in all

parts of the hearth; under the influence of the powerful blast (the pressure of which is about the same as at the blast furnace) the pigs are soon melted and the operation of refining goes on. A portion of the carbon of the pig unites with an equivalent portion of the oxygen of the blast, and is driven off in the form of carbonic acid. In about two hours the metal is in a proper state to run out. A hole at the bottom of the hearth in front is tapped, and the metal flows out along a short channel into an oblong flat mould of stout cast iron, about twenty feet long by two feet broad, placed over an iron cistern, through which water flows, which serves to cool the fluid metal, and to prevent the mould from cracking. A quantity of cinder which flows out with the metal rises to the surface, and is run off through a hole made in the sand which forms one of the short sides of the mould. As soon as the metal is set, this sand is removed, and the plate is turned out of the mould into a trough of water, which *quenches* it, and makes it very hard, brittle and sonorous. Its fracture presents a bluish or a silvery white colour according to its hardness.

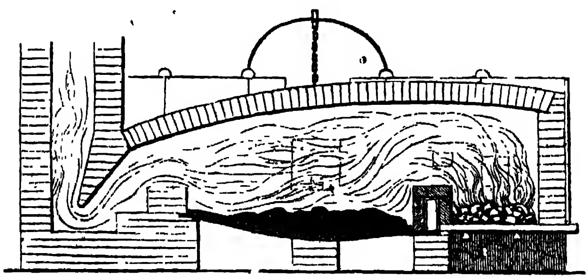
The finery furnace is worked day and night, (Sundays excepted,) with a double set of men. The mould of metal, weighing about a ton, is run out every two hours; so that the quantity of refined iron produced from a double furnace in one week will be about sixty or seventy tons. The pig iron suffers a loss of about ten per cent. in refining, but this varies considerably according to circumstances.

PUDDLING.

THE process of refining does not separate carbon from the pig iron sufficiently for the purposes of the forge. The plate of iron from the finery mould is therefore broken up, and weighed out into portions of about four hundred weight each, called *heats* of metal,

and consigned to the puddling furnace, where the metal is still further decarbonized.

The puddling furnace consists of a fire, the flame of which, by a peculiar construction of the brick work, is *reverberated* or reflected down upon the iron situated in the space between the fire and the chimney, as shown in the following section. The bottom of the furnace is formed of a thick cast iron plate, protected by a coating of the oxide or cinder formed in puddling. The chimney is about thirty feet high, and has a damper at the top, by which the draft is



SECTION OF PUDDLING FURNACE.

regulated. This can be made so strong as to carry the flame out at the top of the stack in contact with the damper. The iron is put in and taken out of the furnace by a large square opening, which, except on such occasions, is kept covered with an iron door, made to slide up and down by means of a lever and chain. At the bottom of this door is a small hole, through which the puddler introduces his tools, and inspects his work. The fire is fed by a small hole at the side called the *stoke-hole*, which is usually kept stopped with a piece of coal.

The metal is put into the furnace with an instrument shaped somewhat like a baker's wooden shovel, the door is then carefully closed, and all allowed to remain quiet for about half an hour, when it begins to melt. The puddler then introduces a bar, turned

at the end like a hoe, and arranges the pieces of melting metal in such a manner that all may be equally exposed to the action of the flame, and melt as nearly as possible at the same time. If this is not done, the portions which melt first burn away and are lost. When the whole is melted, he stirs it up in all directions, so as to expose every part in its turn to the action of the flame, and occasionally throws small scoopfuls of water upon it. The tool, of course, soon becomes red hot, and must be changed for a cold one,

PUDDLING

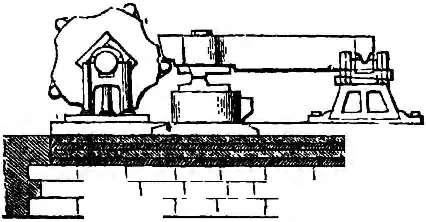
the hot one being thrown into a trough of water as soon as it is withdrawn. The liquid metal heaves and boils and is covered with bubbles, which, as they burst, give out little jets of white or blue flame. After a time this boiling ceases; the mass gradually becomes thicker, and as it is turned over it presents a curdy appearance, the small points and corners glowing with a white heat, while the mass itself looks cooler. In this state the workman says it is "coming

round to nature." He continues to stir it vigorously until it becomes tenacious enough to stick together and form into lumps. *He then divides it into four, or five separate portions, made as round and compact* as possible; this is called "balling up," and the balls are called "puddler's balls:" this finishes the operation of puddling. A puddler works about six or seven heats in the course of twelve hours.

SHINGLING.

The balls formed by the puddler are taken out one by one by means of a pair of tongs, as shown in the cut at page 55, the puddler's assistant holding up the door of the furnace, and letting it drop as soon as a ball is taken out, in order to economise the heat of the furnace. It is dragged along the floor by means of the tongs to the shingling hammer, where it receives a few blows, the effect of which is to make the ball more solid, and to reduce it to an oblong shape, better fitted for the next operation of rolling. It also forces out a portion of the liquid cinder which is separated from the pure iron in puddling.

The shingling hammer weighs about four tons, and consists of a ponderous cast iron shaft or *helve*,



SHINGLING HAMMER.

through the head of which the hammer is inserted. The hammer is lifted by means of a *cam*, revolving under the tennant or nose of the helve, consisting of

three or four chilled iron levers turning upon an axis, so that as they act in succession upon a projection under the helve, *the hammer is made to rise and fall as required.*

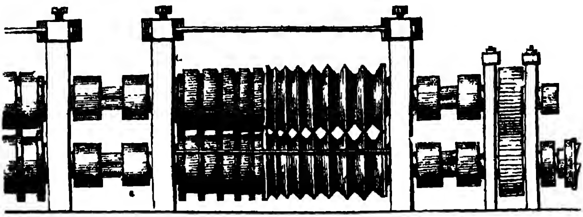
As soon as the ball of iron is under the hammer, the shingler throws aside the tongs, and receives from his assistant an iron bar which has been heating for the purpose in the stoke-hole of the puddling furnace, and placing one end of this upon the bloom the hammer forces it into the semi-fluid mass, and with this the bloom can be turned over and over so as to receive the strokes of the hammer to advantage. From ten to twenty blows are generally sufficient to produce the effect required. The bloom hisses, bubbles, and flames under the operation, and sparks fly off and streams of cinder gush out with considerable force in all directions, making it necessary for the shingler to wear very thick leather leggings and apron. If the puddling has been properly done, the bloom is brought to a firm and tenacious mass; but if the puddling has been neglected, some portions of the bloom will be harder than the rest, and will not adhere well together. Such a bloom is termed a *shadrach*, and is returned to the puddler, who is fined for his neglect.

ROLLING.

THE bloom being properly shingled is handed over while still at a bright red heat to the roller, who passes it quickly through the *puddle-rolls*, using first the largest hole and then the smaller ones in succession. A lad on the opposite side, called the *catcher*, receives the bloom with a pair of tongs every time it goes through the holes, and passes it over the rolls to the roller.* When it has gone through all the holes of the first pair of rolls it is passed through

* See Frontispiece.

the different grooves of the second pair, where it is reduced to a more accurate form and to the dimensions required. In passing between the rolls a further portion of cinder is driven off, the greater part of which falls into a hollow space beneath.



PUDDLE BALL ROLLS.

The puddler is paid according to the weight of rough bars produced; the yield of each puddling furnace is therefore arranged in a separate division, as shown in the cut at page 55. 22 cwt. is about the quantity of metal required to make a ton of rough bars.

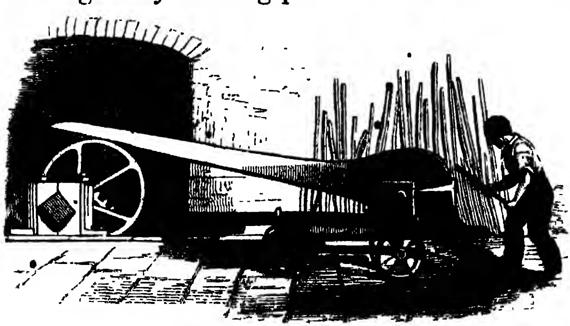
The shingling hammer, the rolls, and other machinery of the forge, are of very massive construction. A firm foundation is formed by heavy cast-iron plates imbedded in masonry underground, where also the uprights or sides of the rolls are securely fixed, and a number of wheels and shafts arranged for giving the required speed to the different sets of rolls. Hence the weight of machinery underground is almost equal to that above, and renders it difficult to trace the connexion of the different parts of the machinery with the steam engine.

The rolls are made of bright iron of the hardest quality, and are cast solid. They are then turned to the required shape with steel tools, the motion being very slow to diminish the heat excited by the friction, or they would otherwise soon lose their edge. In mounting the rolls in the forge brass bearings are provided, as also for the axles of wheels and the ends of shafts, the friction between two different

metals being much less than between two pieces of the same metal. The points of friction are also kept well oiled, and perfectly cool by streams of water.

After the iron has passed through the first two sets of rolls the operations at the forge are completed. It has been brought to the state of rough bar, very different from the pig iron used to produce it. This was very hard, very brittle, and readily fusible; it is now a long slender bar of soft, tough, malleable iron, fusing with difficulty; and this remarkable change is supposed to be produced merely by the separation of a little oxygen and carbon from the pig iron. The subject is by no means well understood, and it is to be hoped that advancing chemical knowledge will throw light upon this as well as many other interesting processes in the manufacture of iron, the theory of which is still obscure.

The bar iron is not yet fit for the market; its surface is scaly and uneven; its edges are rough and imperfect, and it is too unsound in texture for the use of the smith: the bars are therefore further purified at the *mill*, for which purpose they are cut into lengths by a strong pair of shears. The rough

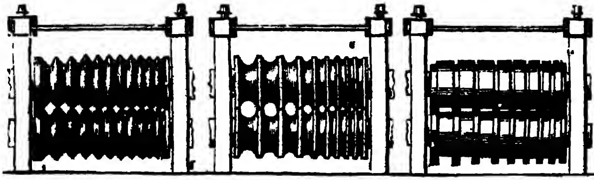


bars are generally two, three, or four inches in width, and half an inch or rather more in thickness, and the

lengths into which they are cut are of course adapted to the size of the finished bar. Equal lengths are made up into piles, each consisting of several pieces placed evenly one upon another. These piles are then placed in a balling or heating furnace, which is a reverberatory furnace, similar in construction and shape to the puddling furnace; but instead of having a coating of oxide of iron or of cinder at the bottom, it is kept covered with loose sand.

It is of importance that the piles be formed evenly, and with no projecting or ragged edges, because when placed in the furnace these become heated first, and begin to burn away before the rest of the pile is hot enough for rolling. Considerable care and experience are required to decide when the piles have attained the proper welding heat, and also to prevent those from burning which are ready to be taken out; but if the roller is not quite ready for them, a handful of sand thrown over the pile is the usual expedient to prevent burning. For small bars as many as twelve or sixteen piles are put into the furnace; for large ones not more than four or five are put in. The cinder separates itself from the iron while in the balling furnace; first appearing as a sort of glaze over the pile, and then flowing away down the bottom of the furnace, which is made with a slope for the purpose of carrying off the cinder.

Each pile, as soon as it is taken out of the furnace, is passed between rollers, which are of great variety, according to the kind of bar required, such as round, square, or flat; and there are also three sizes of each;



FINISHING, OR BAR ROLLS.

the largest being about 14 to 16 inches in diameter; the middle 10, and the small rolls 7. The large rolls move at the rate of about 70 revolutions in a minute; the middle sized rolls 140, and the small ones 230 or 240. *Roughing rolls* are first used to bring the bar nearly to the shape required; it is then passed through the *finishing rolls*, which complete the work. In passing through the several grooves of each roll the pile gradually diminishes in size, and the pieces composing it become firmly welded together, and at the same time elongated into a bar, any remaining portion of cinder being also squeezed out. The roller and his assistant do their work as quickly as possible, that the bar may not be too cool to pass through the grooves, for if such be the case it must be heated again before it can be finished.

The separate pieces which compose the pile produce a fibre in the bar, which adds greatly to its strength and toughness. In good iron this fibre is always perceptible, however perfect the weld. In rolling flat bars the layers of the pile are kept horizontal, in order that the fibres may be as straight and parallel as possible. The experienced blacksmith in working up his bars always attends to the direction of the fibre, because by doing so he can make the most of his iron, and increase the strength and toughness of the articles produced.

In rolling iron there are always certain little irregularities in the work produced, which have been noticed by a practical writer in the following terms:—"However true the rolls may be formed there will always be a little space between them, which will prevent the angles of the square bar formed at their junction, from being so perfect as those formed in the moulding of the roll itself. When the bar, therefore, has been reduced to the required size, it is again put through the same groove, turning it so that the angles shall be changed, those formed before at the sides being now at the top and bottom, by which means

they are sharpened and corrected. Round iron also, being formed between the two semicircular grooves of the two rolls, is liable to the same imperfection unless it is passed several times through the last hole; and even this repetition does not succeed, unless the bar, during its progress, be held in its position by the roller; otherwise it will twist round and adapt itself to the same situation in the rolls that it before occupied, the streak, or *finn* as it is called, still remaining."

Small iron is not manufactured in the same way as the large; instead of piles, *billets* or single pieces of bars are used, cut into lengths adapted to the size of the finished bar. Small iron requires to be rolled at a greater speed than large sizes, as it becomes cold so much sooner. Very small sizes are rolled in long lengths, often as much as forty feet, and are afterwards cut into two or three lengths for the market. The bars thus rolled have a better appearance than short lengths, and are no more trouble to the roller, who can roll a long piece with as much facility as a short one. It is of importance that small iron should be smooth in appearance and accurate in size; and to ensure these desirable qualities, the small rolls are *casehardened* in the casting. This is done by running them into a thick solid iron mould, the effect of which is to cool the iron suddenly on the outside, thereby giving it the hardness and appearance of white iron on the surface, the inside remaining dark grey or bright.

When the rolling is complete, the bars are straightened, which is done by boys on a long bench of cast iron; they are then stamped with some letter or mark to distinguish the works where they are made; the ends are next cut off with powerful shears, and they are then ready for the market. Small iron is put up in bundles, each containing a hundred weight or only half that quantity.

In most of the large iron works iron is sent out in

other forms than those of bars. The vast extension of our railroad system, the use of iron ships and steam boats, and other causes, have increased the consumption of iron to an enormous extent, so that the manufacture of boiler plates, iron rails, tires for wheels, &c, now forms an important addition to the labours of the forge. There is also a constant demand for sheet iron of all sorts, hoop iron, spade iron, slit nail rods, &c, as will be further noticed in the next treatise.

Boiler plates and sheet iron are rolled between perfectly plain rolls, as shown in the frontispiece. This is laborious work for the rollers, especially as the plates often weigh several hundred weight each,* and the very large extent of heated surface causes the men to be constantly bathed in perspiration. "The iron for them is prepared by making a pile of rough bars, which is heated in a puddling or balling furnace, and brought under the forge hammer, where, by repeated blows, it is beaten into a solid slab of about two or three inches thick and nearly square, long and broad according to the weight and shape of the boiler plate for which it is destined. It then requires to be again heated, as it has become too cold under the hammer to be rolled at the same heat: when heated again it is rolled to the proper thickness, the rolls being brought nearer to each other by screws every time it passes between them. It is also brought to the required shape by passing it through the rolls in different directions, sometimes lengthwise, and sometimes with the side or one corner foremost. A skilful roller will in this way bring it very nearly to whatever dimensions are wanted, so that the ragged and uneven edges which are afterwards to be cut off shall amount to as trifling a sum as possible."

* Some works can produce boiler plates up to ten or twelve hundred weight in one plate.

VARIETIES OF MANUFACTURED IRON.

THERE are various qualities of bar iron as of every other manufactured article. There are three qualities known in the market by the names *common iron*, *best iron*, and *best best* or *chain cable iron*; the materials for the superior sorts being selected with greater care, and special attention being paid to the puddling. In making the best iron, *scrap iron*, or the short imperfect pieces cut off the ends of the finished bars, is used in the balling furnace. The manufacture of cable bolts will be noticed in the next treatise.

Two common defects of bar iron have given rise to the well known names of *red short* and *cold short*. Red short iron is that which cracks when bent or punched at a red heat, although it may be very strong when cold. Cold short iron, on the contrary, is weak and brittle when cold, but can be worked without difficulty when hot. "The method of trying the quality of iron is to nick a bar at one side with a chisel, and then to break it, or double it down, as the case may be, at the notch. If the iron is cold short, it will break off at once with a blow of the sledge hammer." The cause of iron being red short appears to be overheating in the balling furnace. "If upon trial the bar should be of good quality, instead of breaking short off it will bend double, and those portions of it to the depth of the notch on both sides will separate a little from the body of the bar, and split up, just as a piece of fresh ash stick would do, and will exhibit a clear, distinct, silky fibre. If this appearance is shown on the trial of the bar cold, and if it is then taken to the smith's shop and bent double at a cherry-red heat, first in the direction of the pile, and then at right angles to it, without being at all cracked on the outer side of the bend, it may safely

be pronounced to be of excellent quality, neither red short nor cold short." A cold short iron is generally produced from a lean ore, in which case it has been found desirable to mix with it the rich red hepatic ore of Lancashire and Cumberland, which if smelted by itself would produce a very red short iron. In this way two opposite defects are made to correct each other, and iron of average strength is produced. This richer ore does not require roasting, but is put into the furnace in the state in which it is brought from the mine.

Another variety of manufactured iron is *charcoal iron*, so called on account of charcoal being used in the refining. When the bloom is removed from the charcoal fire, it is placed under a heavy hammer and beaten out flat, in which state it is called *stamped iron*. It is then broken up into small pieces, piled, heated, and again hammered out into a regularly shaped slab of about a hundred pounds weight. This sort of iron is peculiarly tough and strong, and is much used for drawing into the best descriptions of wire, such as those used for carding;* it is also in great request for rolling into thin sheets for the use of the tin-plate manufacturers.

STATISTICS OF THE IRON MANUFACTURE.

Our means for ascertaining the quantity of iron produced in Great Britain are not very precise. The following estimates, however, are very near the truth, and show in a striking manner the rapid growth and importance of this source of national wealth.

In 1740 the quantity of iron manufactured in England and Wales was estimated at 17,350 tons, the produce of 59 furnaces in which charcoal was

* See the Treatise on the Manufacture of Cotton Yarn, Part II.

used. Between that period and 1788 the use of coke in the blast furnace gradually came into use, and in the latter year there were in Great Britain 85 furnaces, producing annually 68,300 tons of iron. In 1798 the number of furnaces was 121, and the quantity of iron produced 124,879 tons. The following table, drawn up by Mr. Porter from the evidence of Sir John Guest, before a committee of the House of Commons in 1840, will show the increase in the iron trade from the beginning of the present century.

Years	British Iron made.	Foreign Iron used.	British Iron Exported.	Hardwares Exported.	Remained for Home use.
1806	258,000	27,411	36,925	4,629	243,857
1823	452,000	9,667	46,413	10,375	404,879
1825	581,000	14,977	34,372	10,980	550,625
1828	703,000	13,984	65,139	12,100	639,745
1835	1,000,000	17,571	199,007	20,197	798,367
1836	1,200,000	18,920	192,352	21,072	1,005,496
1840	1,500,000	13,263	268,328	14,995	1,229,940
1841	1,500,000	17,653	360,875	17,667	1,139,111
1842	1,200,000	14,711	369,398	15,212	830,131
1843	1,200,000	12,069	448,925	17,183	745,961
1844	1,400,000	21,599	458,745	22,552	940,302

"This rapid and great increase shown in the last few years, has been in some part caused by the economy introduced through the use of the hot blast in smelting, a process which has materially lowered the cost of iron, and therefore has led to its employment for many purposes in which its use was previously unknown." *

The effect of the increased economy in the production upon the price of bar iron will appear from the following table, quoted from the selling prices of English merchant bar iron in Liverpool.

* Porter's Progress of the Nation, 1847.

	£	s.	d.					d.	
1806	17	10	0	per ton.	1841	7	15	0	per ton
1810	14	10	0	—	1842	6	0	0	—
1815	13	5	0	—	1843	5	0	0	—
1820	11	0	0	—	1844	5	10	0	—
1825	14	0	0	—	1845	8	5	0	—
1830	6	0	0	—	1846	10	10	0	—
1835	7	10	0	—	1847	10	10	0	—
1840	8	10	0	—					

The distribution of the iron trade of Great Britain, and the quantity of coals used in the manufacture, about the year 1840, will appear from the following table published in October of that year by Mr. Jessop, of the Butterley Iron Works in Derbyshire.

	Tons of Iron made.	Tons of Coal used
Forest of Dean	15,500	60,000
South Wales	505,000	1,436,000
North Wales	26,500	110,000
Northumberland	11,000	38,500
Yorkshire	56,000	306,500
Derbyshire	31,000	129,000
North Staffordshire	20,500	83,000
South Staffordshire	407,150	1,582,000
Shropshire	82,750	409,000
Scotland	241,000	723,000
	1,396,400	4,877,000
Coals used in converting the pig-iron into wrought iron		2,000,000
	Total	6,877,000

In the year 1845, the quantity of British iron exported was as follows:—

	Tons.
Pig iron	77,362
Bar iron	153,813
Bolt and rod iron	10,210
Cast iron	22,036
Iron wire	1,949
Anchors, grapnels, &c.	2,975
Hoops	11,739

	Tons.
Nails	6,463
All other sorts of wrought iron, except Ordnance	56,165
Old iron for re-manufacture	6,251
Unwrought steel	7,015

Of British hardware, there were 20,754 tons of the declared value of 2,183,000*l.*; and of machinery the declared value of 904,961*l.* exported.

RED AND BLACK VASE.

WITH A ZONE OF WHITE IN THE MIDDLE.

COVERED VASE WITH RED AND WHITE ORNAMENTS ON A BLACK GROUND.

URN-SHAPED VASE, RED AND BLACK.

RICHLY ORNAMENTED COVERED VASE.

YELLOW VASE WITH ORNAMENTS IN BLACK AND RED.

GRECIAN VASES.

THE USEFUL ARTS

MANUFACTURES OF GREAT BRITAIN.

THE MANUFACTURE OF POTTERY, PORCELAIN, AND ENCAUSTIC TILES.

HISTORICAL NOTICES OF EARTHENWARE.

"Two substances only, rich in instruction for the history of society, and of the globe itself, have been able to traverse accumulated ages, and bring to us the first glimpses of ancient times and people: these substances are, first, baked earth fashioned into vases and utensils of various sorts; and, secondly, the solid parts of animals and vegetables reduced to a fossil state."

Great historical importance is given to *pottery* (or the art of making earthen vessels) in the above remark, made by the late eminent director of the porcelain manufactory at Sevres;* nor does it appear that he has exalted it too highly when we consider the inefficiency of most substances as records of the past. Metals are difficult to extract from the earth, the common kinds being likewise subject to corrosion, and the precious metals extremely rare: the most lasting kinds of stone are also difficult to work, and have been necessarily of limited use: wood, which can be worked with ease, is not sufficiently durable to be of historical importance;—but clay, which lies almost at the surface of the earth, and

*Alexandre Brongniart.

within reach of every one, and which the most ignorant may fashion into vessels, and by the simplest means render durable; this substance is indeed historically valuable, and may well be said to have rendered the same kind of service in reading the history of remote ages, that printing has done for the more enlightened.

The antiquity of the art is established by numerous and authentic memorials, so that it ranks next to the arts of making defensive weapons, and of fabricating from the skins of animals, or from vegetable fibre, a coarse kind of clothing. The word *pottery* is derived from the Latin word for a drinking vessel, and the earliest destination of earthen vessels was doubtless for the common purposes of domestic use. But there was a higher purpose to which they were likewise devoted, and which has been the means of preserving to us many interesting relics of the past: we allude to the religious use of earthen vessels of various kinds, and the custom of placing them in tombs and barrows along with the remains of the deceased.

Funeral vases in great variety, from rude and simple forms to those that are graceful and elaborate, have been found in the tombs of most ancient nations. An incalculable number have been met with in the burying-places of the ancient Britons, Scandinavians, Germans, French, Celts, Etruscans, Greeks, and Romans; and this practice has been also traced in America, among the ancient Peruvians, Chilians, and Mexicans. Earthen vessels in such situations remain almost unalterable, while weapons and even medals are corroded, and in the course of long ages are either rendered shapeless or destroyed. The following woodcut represents the interior of one of the tumuli so common in the north of Germany, and the sort of vessels that are found therein. These latter were doubtless the depositories of the ashes of the dead, as no skeleton or bones were found in the tomb. In many cases, however, the skeletons still

INTERIOR OF A TUMULUS NEAR RADEBERG.

remain, with vases placed at the feet, and sometimes at the head also, or hanging on pegs from the sides of the tomb.

The following figure shows one form of arrange-

ARRANGEMENT OF VESSELS IN A TOMB NEAR CASTEL, IN THE DUCHY OF NASSAU.

ment of vases in those tombs where the body has been burnt, and the ashes are deposited in a central urn, surrounded by smaller vessels. The urns repre-

sented were found near Schierstein, in Nassau, the four smaller ones were inclined towards the large central urn which contained the ashes. The remaining vessels were some of glass, others of pottery, and had contained different liquids, such as wine, milk, balm, oil, &c.

This is not the place to consider the meaning and probable origin of this wide-spread custom, respecting which much difference of opinion exists among archæologists; but it is not a little remarkable that among so many distant nations, having different languages, habits, and superstitions, the practice should have been so much alike in all, and that pottery should everywhere have been considered a necessary part of the furniture of tombs. This circumstance, among others, speaks plainly of the common origin of mankind, and of certain religious views, however dim and degenerate, which continued for ages to pervade the scattered family.

But while there is this general agreement in the nature and uses of ancient pottery, there are also distinctive marks peculiar to each country, and these marks are generally constant. The nature of the material, the general mode of fashioning it, the forms and ornaments, change not, as in the capricious manner of modern times, so as to destroy the nationality of the work; therefore these potteries become exceedingly valuable, in cases where they are very simple, as well as in those, such as the Grecian vases, where they largely reveal the history of the religion, wars, government, and civil and domestic habits of the people.

The potter's art is referred to in the Holy Scriptures in illustration of the weakness and fragility of man, and the omnipotence of God. The prophet Jeremiah was commanded to go down to the house of the potter, and "behold, he wrought a work on the wheels. And the vessel that he made of clay was marred in the hand of the potter: so he made it

again another vessel, as seemed good to the potter to make it." The word of the Lord then came to the prophet, saying, "O house of Israel, cannot I do with you as this potter? saith the Lord. Behold, as the clay is in the potter's hand, so are ye in mine hand, O house of Israel."* This lesson was repeated in a very significant manner before the ancients of the people and of the priests, when the prophet by the command of God took a "potter's earthen bottle," and brake it in their sight, saying, "Thus saith the Lord of Hosts, Even so will I break this people, and this city, as one breaketh a potter's vessel, that cannot be made whole again."†

The art of pottery can be traced in Egypt to a period extremely remote, for it is stated that all the processes of mixing the clay, and of turning, baking, and polishing the vases, are represented on the tombs of Thebes. The clay was kneaded with the feet, then formed into a mass of convenient size with the hand and placed on the wheel, which seems to have been of very simple construction, and turned with the hand. The various forms of the vases were made out with the finger during their revolution; the handles, if they had any, were afterwards affixed to them; and the devices and other ornamental parts were traced with a wooden or metal instrument, previously to their being baked. They were then placed on planks of wood to dry, and were afterwards arranged with great care in trays, and carried, by means of the usual yoke, borne on men's shoulders, to the oven. The potter's wheel was known at the earliest epoch of Egyptian history, of which the sculptures have been preserved, previous to the arrival of Joseph, and long before the foundation of Athens, which is sometimes said to have been the place where the potter's wheel was invented.

Instead of attempting a general description of ancient pottery, which would far exceed our limits,

* Jer. xviii. 3—6. † Jer. xix. 10, 11.

it must suffice to present a few specimens of these interesting relics, as they have been brought to light in various countries.

To begin with our own country and capital. A great number of antiquities have been dug up on the shores of the Thames, near new London Bridge, among which specimens of pottery and of tiles are numerous, the greater part being apparently of Roman workmanship, of which we have selected a beautiful fusiform *Amphora* as an example. Some

ROMAN AMPHORA.
DUG UP NEAR LONDON BRIDGE.

ANTIQUE URN,
FOUND NEAR CIRENCESTER.

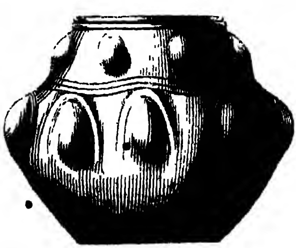
urns in black clay, and many other objects in earthenware, glass, and bronze, are not so evidently of Roman origin. Funeral urns and other relics have been found in the county of Gloucester, of which the above was discovered near Cirencester, being half-filled with burnt bones. Some interesting decorated urns were found at Colney in Norfolk. They were made of a coarse kind of clay, blackish in the middle of its thickness, but reddish brown on the outside, which is polished. They contained bones, ashes, and charcoal. Near Norwich was also found an ancient urn, with a remarkable ornament in relief. Like-

wise a thick black vase with seven knobs upon the neck, and seven upon the body. It has not been turned. On the downs of Wiltshire there are very

COLNEY IN NORFOLK.

ANCIENT URN, FOUND NEAR NORWICH.

many of those repositories of the ancient dead, which contain pottery. The urns are in some cases perfectly plain, in others they appear to have been ornamented by the pressure of the thumb, or the markings of the finger-nail, or more highly finished by means of some tool. From among the numerous specimens



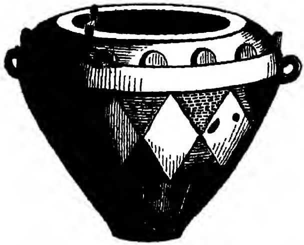
BLACK VASE, FOUND NEAR NORWICH.

SEPULCHRAL URN, FOUND NEAR WILSFORD, WILTS.

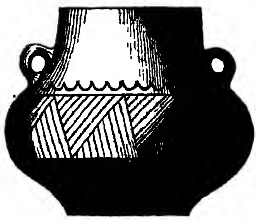
thus collected in Wilts, we select a beautiful, though irregularly formed, sepulchral urn, found in one of the

barrows of the Wilsford group. This urn was placed in a circular cist, and contained a deposit of burnt bones. Close to this urn was another oval cist containing ashes, together with a spear-head of brass, which appears to have been almost melted into a rude lump, by the heat of the funeral pile. This barrow appeared to be a family sepulchre, as there were signs of three interments within a very short distance of each other. An interesting collection of urns, variously ornamented, has been found in the Deveril barrow, in Dorsetshire. Many were in a dilapidated state, and required great care in the removal. Their discoverer (W. A. Miles, Esq.) found that the best method of doing this was to make fires near them, and evaporate the moisture from the clay, which in the more ancient examples is of a porous nature. This process of evaporation was sometimes kept up until after night-fall, and Mr. Miles describes the scene on the downs as highly picturesque, while fagots were blazing, and revealing by their flickering light the anxious and half-terrified looks of the labourers, poring over these sepulchral urns, and viewing with wonder and awe the ashes of the dead contained therein. The county of Kent has also produced its relics. Near Southfleet some large urns were found, containing burnt bones and broken pieces of glass. Near the Margate sands, at the mouth of the Thames, a great number of antique earthen vessels and fragments have been brought up in fishermen's nets, several of which are inscribed with the maker's name, *Attilianus*, which sufficiently proves their Roman origin. Further researches have brought to light the fact that about two hundred years before the conquest of Britain by Julius Cæsar, there existed upon an island at the mouth of the Thames a manufactory of pottery, possessed by Attilianus. The Margate sands are all that remains of this island, and the particular part known as Pudding-pan sand (on account of these fragments) was doubtless the site of the factory.

Germany is very rich in ancient urns and potteries. The following elegant urn, much decorated with designs in grey clay, was found in a large tomb, near

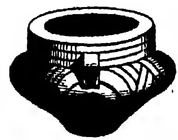


URN FOUND IN A TOMB NEAR HALLE.



GERMAN VASE, PLACE UNKNOWN

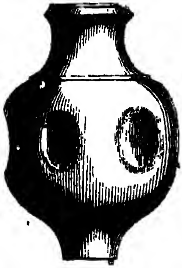
Halle. The vase with two small handles on the neck is also German, although the exact place in which it was found is now unknown. The small urn was found with about 150 others in a tumulus on the right shore of the Elbe, near the mouth of the Black Elster, in the ancient place of sacrifice.



FROM A TUMULUS ON THE SHORE OF THE ELBE.

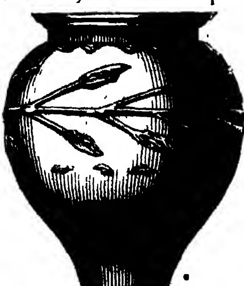
In various parts of France there have been rich discoveries of ancient pottery, especially on a hill between St. Dizier and Joinville, in Champagne, where the ruins of a Roman town were brought to light in 1772. Here were found two potter's kilns and a number of culinary articles: some unglazed, others covered with bright red glaze, and elegantly ornamented in relief. All these vessels are marked with the potters' names. Not far from Dieppe, a number of potteries, in fine ash-grey clay, have been met with, and among them the urn here represented, which is very remarkable for five depressions in its sides, which seem to have been made for the accommodation of five little urns, which were placed close around the principal one. An elegant vessel, in coarser clay, of the same colour, was found at the same place, and

is considered to be Gallo-Roman, of the age of the Antonines.


URN FOUND NEAR DIEPPE.


VASE FOUND NEAR DIEPPE.

Roman Pottery was fashioned with great care, and by means of processes which are still in use. The lathe-wheel was constantly employed for round articles, and the ornamental part was done by means of moulds, or of roulettes bearing the ornaments which were to form circular zones upon the circumference of vases or cups, or by stamps or seals, which were chiefly used for figures or flowers, to be placed in the centre of other ornaments. The names of the workers, so frequently found at the foot of Roman vessels, were also produced by a sort of stamp, made sometimes of hard-baked clay, sometimes of metal. There was a fourth method of applying ornaments to these potteries, which is remarkable, and seems to be distinctive of Roman workmanship. This was to charge a pipette or a spoon-shaped spatula with a portion of clay in nearly a liquid state, and apply it to the surface of the article to be ornamented, moulding it into the required shape, such as stems, foliage, &c. In this way, by using differently coloured clays, a pleasing effect was produced. Thus, a flower-


ROMAN VASE, FOUND AT ZAHLBACH.

ing branch was formed in white clay on a vessel of the ordinary red pottery. A pipette, supposed to have been employed for this purpose, has been found among the pottery. The ancient Roman kilns in which their pottery was baked, have been found in considerable numbers in Germany, France, and England. The articles produced are generally simple and somewhat massive in form. The amphoræ, or wine jars, with two handles, are often of graceful proportions.

In ancient Greece, and in all her colonies, a simple kind of unglazed earthenware seems to have been made from the earliest times; but many of the glazed specimens are also of such high antiquity, that it would appear that the omission of lustre was voluntary, and did not arise from inability to produce it. Etruscan pottery appears to have been the work of less clever workmen, and to have been made without the advantage of the turning-lathe, and without glazing. The greater part of the Etruscan vessels (properly so called) are, therefore, of unequal thickness, and badly moulded, although often of agreeable forms, and ornamented with taste and care. The adjoining is a representation of an Etruscan urn, in black clay, much ornamented, but with


ETRUSCAN URN.

some irregularities in the shape and position of the figures, &c. Some of the most admired vases called Etruscan, are attributed to the Greek potters of the isle of Samos, so celebrated for the cleverness of their

works. Recent discoveries in Etruria have brought to light a great number of beautiful vases, having all the characters of Greek pottery. So great is the delicacy and perfection of many specimens of ancient

GREEK VASE

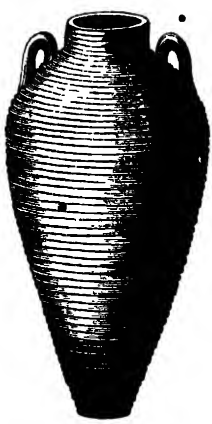
Greek art, that they are viewed with astonishment by modern workmen, who know the difficulty of producing such results. At the manufactory at Sevres, some of these specimens have been given to the cleverest artificers, as problems in workmanship which they were to solve, not by explanations, but in practice. The methods employed in working out these problems are given in Brongniart's admirable work on Potteries. The adjoining engraving represents a Greek vase, in which the figures are red, on a black ground. The other illustration is of a covered cup or vase, having a similar mode of ornament. In

GREEK VASE.

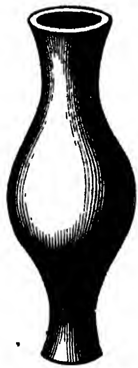
the frontispiece are other specimens of Greek ornamented vases.

The ancient pottery of Egypt is less interesting than might have been expected from a people whose architecture, statues, and customs, generally possess

so much originality. There are not many forms in their vases and utensils of clay which are striking as characteristic of Egypt, nor do the ancient greatly differ from the modern examples. Many of the ornamental vases, represented on tombs, are curious and interesting; but there is every reason to believe that these were executed in metal. The two following examples of unglazed pottery are of a long oval-shaped vase, with two small handles, found among the ruins of Antinoë, and a simple fusiform vase, without handle, found in a tomb near the isle of Cephantine.



VASE FOUND AMONG THE RUI OF ANTINOE.



FOUND IN A TOMB NEAR THE ISLE OF CEPHANTINE.

Some interesting examples of pottery, generally spherical, or approaching thereto, and much ornamented with figures of quadrupeds and birds, were long considered to be Egyptian, but are now believed to be Phœnician, or Tyrian.

The potteries of India are of two kinds, the one red or yellowish, the other black. Most of the common culinary vessels have the peculiarity of being hemispherical at the base, being fitted for the

cooking of rice, and adapted to receive the equal action of the fire. They are nearly all thin, light, and very well turned. The black pottery has often a lustre of such intensity as to resemble that of the black diamond. It cannot be attributed to the mere action of fire on the black clay, for it is sometimes deficient in those parts of the vessel where the flame has played strongly: it is rather to be ascribed to some liquid varnish; yet this is so exceedingly thin, that it has not yet been possible to determine its nature. In the Museum of Sevres is a specimen of this pottery, in the interior of which is a proof that the glaze was liquid, since it has flowed down the unglazed side of the vessel.

MARKS OF LIQUID VARNISH ON INDIAN BLACK POTTERY.

The potteries of North and South America are entirely different: those of the north approaching the German and Scandinavian make, while those of the south have a character more peculiarly their own. The ancient Iroquois, and other nations bordering the Ohio, fabricated vessels of large size, both in black and white clay, the latter being very impure, and interspersed with fragments of bivalve shells, either to give the material more tenacity, or for the sake of ornament, the fragments projecting, and forming bright points. In Virginia, poor women apply themselves particularly to the fabrication of pottery. Though fashioned by the hand, the vessels are thin and well made. Some of them resemble those just mentioned in having fragments of shells mixed up with the clay.

The discoveries which have recently been made in Mexico reveal an astonishing amount of architectural and other antiquities. Among the ruins of Mitla, numerous specimens of pottery have been met with, and these, frequently, of a grotesque kind. Others, consisting of jars, ornamented in different colours, and standing on feet, have been found in crypts

and earthen mounds with human remains. The ruins of Mitla and Palenque are considered to have belonged to an empire long anterior to that of ancient Mexico. Its date has, indeed, been assigned at 1000 years before the Christian era. If this be anything like correct, the potteries of Mitla, although made without the turning lathe, must yet be considered remarkably advanced for that period, being well baked, and covered with a fine vitreous glaze, such as was unknown to Europeans until about ten centuries ago.

South American pottery is very abundant, often fanciful, but sometimes of great simplicity, and approaching, in its forms, the Grecian, Etruscan, and Chinese. Nevertheless, much of it is badly made, both the ancient and modern, and thick and irregular in form. The baking of all the pottery is conducted in the open air, without kiln or any other envelope than the burning wood piled around it. The Peruvians are considered the most clever in this art. Many of their drinking cups are made in the shape, not only of fruits, animals, or parts of animals, but of men, and of human heads. This strange and ungraceful fancy is not confined to the Peruvians, but has been displayed by nations far more civilized than they. A great quantity of pottery has also been made in Brazil, where the employment is consigned to poor women. Large urns are fabricated by them for funeral purposes, the body being reduced to the state of a mummy, and then bent together so as to be placed in the urn. If a chief or warrior, it was invested with ornaments and weapons.

HISTORICAL NOTICES OF PORCELAIN.

WHILE the art of making simple unglazed pottery is among the earliest of which we have any record, the perfecting of this art, and the production of the finer kinds of pottery called porcelain, have been of recent date, at least in Europe, and in all other parts of the earth except the east, perhaps solely China.

The name porcelain is of very doubtful origin; but the substance is well known as being a fine hard kind of pottery, compact, impermeable, breaking with a shining fracture like glass, and being invariably *translucent*, or clear enough for light to pass through it, however dimly. These are the characteristics of the pottery of China, which every one considers as true porcelain; and such being adopted as the standard, it follows that the beautiful wares of Italy, and also the so-called porcelain of Egypt, must be excluded from the list. The Egyptian ware, of which so many small figures of Isis are made, is neither compact, hard, impermeable, nor translucent. It has been often confounded with true China, because it is a whitish clay, with a blue or bluish green glaze. But not only does it differ outwardly from porcelain in the qualities above stated, but by analysis it is proved to contain only one out of all the elements of real china, namely siliceous sand. But if it may not rank with the porcelain of China or of Europe, neither may it be compared with any other kind of pottery: it is in fact peculiar to Egypt, and may almost be called an artificial stone, which the Egyptians have enamelled as they have done other stones, such as granite, schist, serpentine, &c.

The origin of porcelain is to be sought for among the Chinese, and although the precise date of the

invention cannot be ascertained, yet it is stated that so early as 2699 years before the Christian era, the emperor Hoang-ti had a superintendant of potteries, and that it was during his reign that pottery was invented by Kouen-ou; also that porcelain was common in China 163 years before Christ. The latter assertion is in some measure confirmed by the fact that many vases of a pure white, but of inferior materials, were found in digging out the foundations of a palace which was built about that period. But it appears that it was not until four or five hundred years after the Christian era that porcelain began to be made with fine materials, and to attain some degree of perfection. Yet this date is sufficient to give a high antiquity to the porcelain of China, and to show that it was made at least 1250 years before our European porcelain. And there was so little change in the methods when once discovered, that in a collection of Chinese porcelain which exists in the Japanese palace at Dresden, and which bears date from 1403 up to 1620, there is not the slightest difference in the specimens, as to the mode of fabrication, the clay, or even the colour.

The Portuguese first introduced Chinese porcelain into Europe in 1518, and it was not till about two hundred years later that the first attempt was made to fabricate this hard porcelain in Saxony. Jean Frederic Böttger laboured long and diligently to find the secret of making porcelain, but could only succeed in making a sort of red ware, which, though greatly inferior to Chinese porcelain, was yet in great demand in Saxony as soon as it appeared. Accident, however, brought to hand the material necessary for success. It happened that a rich forge-master was travelling on horseback, through Aue, near Schneeburg, and observed that his horse's feet sank deep in a soft and white-looking earth, which impeded his progress. It immediately struck the merchant that this white powder might be made an article of

trade, by introducing it instead of the flour of wheat, for hair powder, which was then very much in fashion. He accordingly collected some, and having found it to answer his expectations, he commenced the manufacture, and sold his new hair-powder in large quantities at Dresden, Leipsig, &c. Now it so happened, that some of this powder was used to dress Böttger's wig, and that the wearer observed a difference in it from the common sort, and complained of its greater weight. Questioning his servant on the subject, he learnt that it was earthy in its nature; upon which he tried it in his manufacture of porcelain; when he found to his exceeding joy that he had at length discovered the true secret of producing this beautiful substance, and that with this new earth he could make as white a porcelain as that of China.

This substance was long known in commerce as Snorr's white earth, from the name of the merchant who first discovered it: its exportation was forbidden under the most severe penalties, and it was carried to the manufactory by sworn agents, and in sealed casks. The precautions taken to insure secrecy were indeed almost incredible. The fundamental point of all the instructions given to the work-people was, "Secrecy to the grave." This motto was given out afresh to the superintendents every month, and was affixed to the doors of the workshops, so that all the inferior workmen might be constantly reminded of it. Whoever should betray any one of the secrets of the manufactory was threatened by the king to be shut up for life as a state prisoner in the fortress of Kœnigstein.

The manufactory of Albrechtsburg, at Meissen, was treated precisely as a stronghold, of which the drawbridge was only lowered by night, and entrance was strictly forbidden to all unconnected with the place: even the king, on bringing strangers of distinction to see the place, received a caution not to betray inadvertently any of its secrets.

Such is the account given of the origin of Dresden china, but some discrepancy exists in the dates. The discovery of this white earth is said to have taken place in 1711, while the first sale of white porcelain is described as having been made at the fair of Leipsig, in 1710, and at the same time the period of Böttger's triumph over all his difficulties is given as 1709. However this may be, it is certain that Böttger was rewarded for his exertions by being placed at the head of the new manufactory in the character of director. So successful were his attempts at a complete imitation of the porcelain of China, that the most experienced eye can scarcely detect the difference in colour, form, painting, or gilding, between his works, still exhibited in Dresden, and those of the Chinese. Unhappily for himself, this clever and ingenious man, having attained the height of his ambition, began to take less interest in the subject which had formerly engrossed all his thoughts, and at length giving way to a luxurious mode of life, died at the early age of thirty-five years, in 1719.

The attempts to imitate Dresden porcelain now became numerous, and in some cases the resemblance was considerable, but it was only in external appearance, the essential qualities of good china being wanting. At length, however, certain individuals who did not feel that the stealing of a process is as culpable as any other kind of theft, seduced a few of the workpeople from their allegiance. Thus the Duke of Brunswick won over the potter Bengraf to his interest, who founded, somewhere about the year 1744, the manufactory of Furstenberg, on the Weser. At the same time and even earlier the secret had transpired in other quarters, and the manufacture was carried on in various parts of Germany, so as to become a source of profit to many sovereigns, at the same time that it afforded new objects of splendour and magnificence.

Meanwhile, the emulation of scientific men in

France had been strongly excited, and great efforts were made to produce porcelain equal to that of Saxony. M. Réaumur procured specimens of Oriental, Saxon, and French porcelain, and on breaking them he discovered that while the grain of the Chinese and Saxon pieces was compact, smooth, and shining, that of the French ware was not so close or fine, had no lustre, and resembled loaf sugar. By farther experiments he found that true porcelain is a semi-vitrified compound, in which one portion remains infusible at the greatest heat, while the other portion vitrifies and envelopes the infusible part, producing the beautiful translucent and shining texture. He next examined two sorts of porcelain earth received from China, one of which, called *pe-tun-tse*, was fusible, the other called *kao-lin*, was infusible. The search for material answering to these was diligently prosecuted and at last successful. The finest and most abundant supply of porcelain earth in France was discovered accidently in 1768, by Madame Darnet, the wife of a poor surgeon, who observed in a ravine at St. Yrieix, near Limoges, an unctuous white earth, which she thought might be used in bleaching linen. She showed some of it to her husband, and he, suspecting its real nature, took it to Bordeaux, and made it known to persons engaged in the search after materials for porcelain, who, on trial, found in it the very thing they needed as a base to the real hard porcelain. This discovery, so important to all France, does not seem to have been of any immediate benefit to the surgeon and his wife. M. Brongniart relates that in 1825 Madame Darnet was still living, and came to him in much misery to implore charitable aid, having travelled from St. Yrieix, on foot, to see him. He gave her immediately what she required, and subsequently obtained for her from Louis XVIII. a small pension. This he justly calls a debt, due from France for her discovery, which, though accidental, was the means of opening a vast source of wealth and

industry to the nation. The manufacture of hard porcelain was soon established at Sevres, which had already become celebrated for a very beautiful china, but such as is called *tender* or liable to be scratched. Over this establishment M. Alexandre Brongniart had been placed as director so early as the year 1800.

In thus briefly noticing the porcelain of France, we must not pass over the fact that the art of making glazes for the finer descriptions of pottery was greatly advanced in that country during the sixteenth century, by the labours of an extraordinary man named Bernard de Palissy, who has left a deeply interesting narrative of his labours and sufferings. An enamelled cup having fallen into his hands, he was seized with such an intense desire to produce its equal in beauty, that he gave up every other employment, and devoted his whole mind, time, and substance, for several years, to experiments on the composition of enamel. He even went so far as to reduce himself and his family to want, so as to be compelled to sell his clothing in order to pay his workman's wages; but even then he persevered, and was at length rewarded with complete success. Fame, honours, and riches, were his reward, and he employed a long life in promoting excellent and praiseworthy objects. Being a Protestant, and having in some of his lectures stated facts which gave offence to the priesthood, he was, when in his ninetieth year, dragged to the Bastile by these zealots, and suffered to die in prison. But his firmness of mind did not forsake him to the end; he loved his religion better than he loved his life, as his reply to Henry III. of France sufficiently testifies. "My good man," said the King, "if you do not conform yourself on the matter of religion, I shall be compelled to leave you in the hands of my enemies."—"Sire," replied the aged Palissy, "I was already willing to surrender my life, and could any regret have accompanied the action, it must assuredly have vanished

upon hearing the great King of France say, 'I am compelled.' This, sire, is a condition to which those who force you to act contrary to your own good disposition can never reduce me; because I am prepared for death, and because your whole people have not the power to compel a simple potter to bend his knee before the images which he has made."

Porcelain of the fusible or tender kind had been made in England for a long period prior to the discovery of the mineral substances necessary for making true porcelain. But a manufacture which prevailed to a far greater extent, and was of great consequence to the country, was that of the finer kinds of earthenware, which were brought to great perfection by the celebrated Josiah Wedgwood. Of this admired ware an intelligent foreigner thus wrote—"Its excellent workmanship, its solidity, the advantage which it possesses of sustaining the action of fire, its fine glaze impenetrable to acids, the beauty and convenience of its form, and the cheapness of its price, have given rise to a commerce so active and so universal, that in travelling from Paris to Petersburgh, from Amsterdam to the farthest part of Sweden, and from Dunkirk to the extremity of the south of France, one is served at every inn upon English ware. Spain, Portugal, and Italy, are supplied with it; and vessels are loaded with it for the East and West Indies, and the continent of America."

The great seat of this manufacture is in Staffordshire, where a district seven miles in length, enclosing many towns and villages, is known throughout the kingdom under the title of "the Potteries," while one of the villages, built by Wedgwood himself, is dignified by the name of *Etruria*. In 1686, the earthenware made in this district was of small importance, and the traffic was chiefly carried on by pedlars, or by the workmen themselves; but a few years afterwards there arrived from Holland two brothers named Elers, who improved the manufacture, and introduced the method of glazing the vessels by

throwing common salt into the oven at a certain period of the baking. After them followed a potter named Astbury, who is said to have gained a knowledge of their secrets by feigning to be of weak intellect, and taking some menial office in the Bradwell works. This man appears to have been the first to introduce white stone ware, by employing calcined flints in its composition. This was a great step towards that perfection which was afterwards attained by Wedgwood. But the labours of Wedgwood were of an extraordinary kind, and his discoveries were due, not to happy accidents, but to patient investigation and the most untiring industry. His success becomes all the more honourable when we find that his education had been greatly neglected, and that he had to overcome this serious disadvantage, and to discipline his own mind, ere he could enter on investigations that were purely scientific. And when wealth poured in upon him, it did not unfit him for duty: on the contrary, it became the means of greatly enlarging his sphere of usefulness, for he employed it in the extension of knowledge and in the alleviation of misery among his fellow-creatures. His charities, public and private, were munificent, and at the same time judicious; so that Wedgwood deserves to be respected, not merely as the most successful potter, but as one of the most enlightened men of his day. His principal inventions were a beautiful and useful *table ware*, called by royal command Queen's ware; a *terra cotta* which could be made to resemble porphyry, granite, &c.; *basalts*, or black ware, a kind of porcelainous biscuit having nearly the same properties as natural stone, and striking sparks like a flint; a *white porcelain biscuit* of a smooth wax-like appearance, but with qualities very similar to the basalts; *bamboo* or cane-coloured biscuit of the same nature; and *jasper*, a white porcelainous biscuit of exquisite delicacy and beauty, having properties that especially fit it for the produc-

tion of cameos, portraits, &c., since the ground can be made of any colour, while the raised figures are of the purest white; also a *porcelain biscuit* little inferior to agate in hardness, and much used for mortars in the laboratories of chemists.

The success which attended Wedgwood's processes was doubtless a great cause why the manufacture of porcelain (properly so called) did not advance in England, for many of his wares were so beautiful as almost to supersede the necessity for anything of a higher description. Nevertheless, the discovery in 1768 of certain mineral substances in Cornwall, similar in their properties to the porcelain earths of China, led to the production of a superior quality of china to any that had been previously made in England. For the cause just stated, however, this china was not in great demand. From the time of Wedgwood to the present day the continued industry and growing intelligence of manufacturers have carried forward various improvements both in earthenware and porcelain, and have brought these productions to great perfection. Porcelain is now made in the Staffordshire Potteries, at Derby, at Coalport, near Colebrook Dale, in Shropshire, in the city of Worcester, and at Swinton, near Rotherham, in Yorkshire.

WEDGWOOD'S FACTORY AT ETRURIA, IN STAFFORDSHIRE.

HISTORICAL NOTICES OF ENCAUSTIC TILES.

The art of making bricks or tiles of enamelled pottery is exceedingly ancient, and was applied to the decoration external as well as internal of palaces and temples. A number of large edifices in Persia and Asia Minor are covered on the exterior with such tiles, and sometimes enriched in the interior with historical pictures made with vitrifiable colours. Among the ruins of Babylon a great number of fragments of ornamental bricks and tiles have been found at various times. M. Riche in his visits to those ancient ruins found in most of the excavations "fragments of beautiful pottery, and a great quantity of glazed tiles of surprisingly fresh and brilliant colours." Many of the mosques in Asia Minor are adorned with tiles of this description: that forming the tomb of the children of Ali, near Bagdad, has the two domes completely covered with gilded tiles, while the walls are ornamented with various flowers. This edifice is said to have been built in 1581. There is a palace at Ispahan richly decorated with historical pictures composed of square tiles, in which five or six colours can be traced, and there are several other edifices in the same city, variously ornamented with coloured tiles. A small fragment from the great mosque at Jerusalem was of a beautiful turquoise blue, with ornaments of a deep blue, approaching to black. Another, from Baalbeck in Syria, was of a hard and white, yet porous clay, with a thin pale bluish glaze, and black ornaments. The palace of the Alhambra in Spain is covered almost everywhere with encaustic tiles of great beauty, and one of these,

when examined in the laboratory of Sevres, was found to have a glazing in which lead was present, thus showing that the Arabs were cognizant of this kind of glazing, at least in the fourteenth century. This tile had the motto in Arabic, "*There is none strong but God,*" and this motto is repeated thousands of times on the walls of the Alhambra.

In the museum of the East India Company are some fine examples of bricks and tiles with a brilliant glaze, brought from Gour, not far from Patna. The bricks are covered with rich ornaments in relief, white upon a black or deep blue ground, and in some cases the ornamental part is heightened with green or yellow. There are also red tiles and bricks from Nepal, richly ornamented.

Without further tracing the early history of encaustic tiles, we may simply remark that their use was immense and very widely spread, and that they formed the favourite covering not only for floors, but for walls, and even roofs. In some of our ancient churches specimens may still be seen, and it appears that during the middle ages the custom of inserting in the tiles the arms of founders and benefactors to the edifice became very common. Many of the larger abbeys had kilns of their own for the preparation of these tiles, and from this source also, it would appear the parochial churches were supplied. An ancient tile-kiln was discovered, a few years ago, near Malvern, on land formerly belonging to the Priory there. The ancient pavement of the chapter-house at Westminster may be mentioned as one of the best preserved specimens of encaustic tiles.

In the present day, the taste for this kind of ornament has revived in a remarkable degree, and many of our churches now bear witness to the skill and judgment with which encaustic tiles are employed. The manufacture has, therefore, necessarily become active and important, and the processes are not a little interesting, as our description will presently show.

MANUFACTURE OF EARTHENWARE.*

MATERIALS OF EARTHENWARE.

The two principal ingredients in the manufacture of earthenware are *clay* and *flint*. The choice of the proper description of clay, and the proportion of flint to be added thereto for the production of the kind of ware required, are matters of great importance. In this respect each manufacturer exercises his own judgment, keeping the proportions of these two materials secret; for on them depend the peculiar excellences of his productions. The methods of combining the clay and flint are nearly the same every where.

Four kinds of clay are in common use in the Staffordshire potteries. These are called *black* clay, *cracking* clay, *brown* clay, and *blue* clay. The first two are brought from the south of Devonshire; the others from the Isle of Purbeck in Dorsetshire.

The black clay is so called from its colour, which is due to the presence of a portion of bitumen or coaly matter contained in it, which, however, entirely disappears when the clay is passed through the potter's oven, leaving the wares made of it nearly or quite white. Cracking clay is so called from its tendency to crack during the first burning; an inconvenience which is avoided by mixing it with other clays which have not this tendency: it derives its value from its extremely white colour. Brown clay comes white out of the oven, but is also liable to an imperfection called *crazing*, or cracking of the

* The writer has to offer his best acknowledgments to Messrs. Ridgwood of Hanley, to Messrs. Minton, and to Messrs. Copeland and Garrett, of Stoke-upon-Trent, in Staffordshire, for the liberal manner in which they allowed their extensive works to be inspected, and drawings made, for the purposes of the present treatise.

glaze. On this account some potters reject this clay entirely, but Mr. Parkes thinks the defect to arise from the ware being drawn out of the oven too soon, the glaze, which is a species of glass, requiring as perfect an annealing as glass itself. Blue clay is considered the best for common purposes, and fetches the highest price. It will bear a larger proportion of flint than any other, and on this account will produce a whiter ware.

In addition to these varieties of clay, a fifth is largely employed in the manufacture of the finer kinds of earthenware. This is known by the name of *china clay*, and is found in Cornwall. It is obtained from one of the ingredients of granite, which is often found in nature in a partially decomposed state. Granite is composed of quartz, mica, and felspar; and the last named mineral is the source of china clay. The clay merchants in Cornwall prepare the clay for the potter in the following manner. The stone is first broken up by means of a pickaxe, and then thrown into a stream of running water. This washes off the light argillaceous or clayey parts, and keeps them suspended in the water, while the quartz and the mica thus separated sink at once to the bottom: at the end of these rivulets are *catch-pools*, where the water is dammed up, and time allowed for the pure clay to subside. This being done, the water is drawn off; the solid matter at the bottom is dug up in square blocks, and laid on what are called *linnees*, which are several connected series of strong shelves, arranged so as to allow of a proper circulation of air, in order to dry the clay. This being done, it is packed in casks and sent to the potteries under the name of china clay. Thus prepared, it is a white impalpable powder; and contains sixty parts of alumina and twenty of silica. A portion of undecomposed Cornish felspar is often added to the clay, as it serves by its fusibility to bind the ingredients more closely together. It is worthy of remark

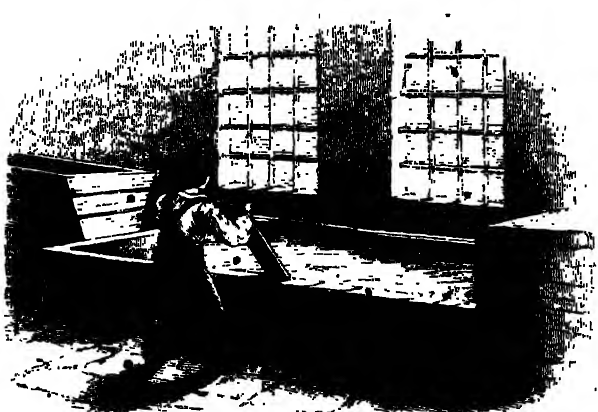
that although neither clay, flint, nor lime can be melted separately in the greatest heat of a porcelain furnace, yet when mixed together in proper proportions one mineral acts as a flux to the others, and the mass can be fused without difficulty.

Steatite or soapstone, a species of mica which is found abundantly in Cornwall, and also in the island of Anglesea, is also occasionally employed in the manufacture of porcelain.

The flints employed in the manufacture of earthenware are obtained from the chalk districts, chiefly Gravesend and Newhaven. They are coated with a white crust, but are dark and clear within. Those which have brown or yellow spots on their fractured surfaces should be rejected, as these marks indicate the presence of iron, which would produce stains in the ware.

PREPARATION OF THE MATERIALS.

The preparation of the materials for the use of the potter is a work of considerable labour and care.



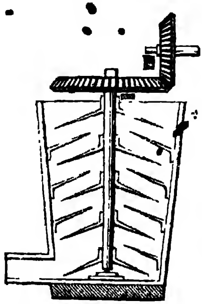
BLUNGING.

The clay is first mixed with pure water to the consistence of cream. This is called *blunging*, and is carried on in a trough about two and a half feet deep, as shown in the figure. The proper proportion of blue and white clay being placed over-night in the trough with a quantity of water, is left to soak until the morning. It is then well incorporated with the water by means of a long blade of ashwood furnished with a cross handle at its upper extremity, and called a *blunger* or *plunger*. This is worked about violently in the trough in all directions until a smooth pulp is produced, a pint of which is, by the addition of water, made to weigh twenty-four ounces; but when china clay is used, a pint is made to weigh twenty-six ounces.

GRINDING THE CLAY

In some establishments mechanical power assists the operation of blunging. The clay is thrown into a cast-iron cylinder four feet deep, and twenty inches

in diameter. Through the centre of this cylinder runs an upright shaft, furnished with projecting knives arranged in a spiral line from top to bottom, so that, as the shaft revolves, these knives not only



cut the clay but force it downwards to the bottom of the cylinder. Parallel with, and corresponding to these knives, a second set is fixed in the interior surface of the cylinder, extending as far as the shaft in the centre; and thus these two sets, one in motion and the other at rest, act like shears, cutting the clay into small pieces: in this divided state it is forced out through an opening at the bottom of the cylinder, whence it is removed to a vat and mixed with water, where the blunging is greatly facilitated by this previous cutting up of the clay. The mixing vat is provided with a perpendicular shaft furnished with cross arms, which by their revolution cause the finer particles of the clay to mix with the water, while any stony particles that may be present sink to the bottom. By these contrivances a pulp is formed as in the process of blunging by hand already described.

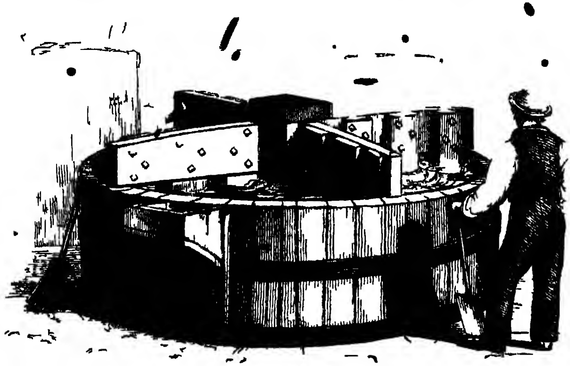
In order to reduce the flints to an impalpable powder, several processes are necessary. They are first burnt in a kiln for about thirty hours, and are allowed to cool before being taken out: in some places however it is the practice while they are at a red heat to throw them into cold water, the effect of which is greatly to increase their brittleness. They are next broken, for which purpose they are placed upon a strong iron grating, and struck by stampers or wooden beams shod with iron, weighing about a hundredweight each, and furnished at the upper part with projections or catch pins, which meeting with similar projections in a wheel on the opposite

side, the stampers are raised in succession; and these, when left free by the rotation of the wheel, fall with great force and break the flints into fragments sufficiently small to fall through the grating.

FLINT MILL

The fragments of flint thus prepared are next conveyed to the flint pan, which is a strong circular vat ten or twelve feet in diameter. The bottom of this vat is formed of quartz or felspar in small blocks embedded in mortar, similar in composition to the material which is to be ground. In the centre of the vat is an upright shaft surrounded by a barrel or hoop fourteen inches high, to prevent the materials from being soiled by the moving power while being ground. Projecting from this shaft are four strong frames which serve the purpose of moving the runners, which consist of a very hard siliceous stone called *chert*, which is found in abundance in the neighbourhood of Bakewell in Derbyshire. Water to the

depth of eight inches being put into the vat, the broken flints or felspar are added, and the central shaft being put in motion, the broken pieces are forcibly rubbed against the runners as well as against each other and the paving of the vat, so that in the course of some



FLINT PAN

hours the flints are reduced to a fine powder, and the mixture has the consistence of thick cream.*

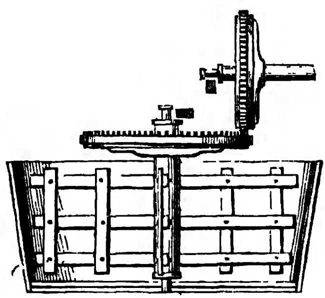
Before the invention of this mill by the celebrated Brindley, the flints were ground dry—an operation almost as fatal to the workmen superintending it as the dry grinding of needles and edge tools is at the present day. The air of the room being charged with the finer particles of the flint, entered the lungs and did much mischief. The introduction of the wet method, however, has entirely remedied this serious objection.

The selection of the stones employed in the construction of the flint mill is a point of great importance, as the goodness of the pottery depends in great measure on this circumstance. Mr. Parkes states that some years ago a very severe loss was sustained

* Smaller pans of the same construction from four to six feet in diameter are used for grinding the felspar, broken porcelain, bone, and other materials used in the composition of earthenware, as also the different glazes used for covering the ware after it is baked.

by many of the first houses in the trade, in consequence of their having been supplied with large quantities of prepared flint which had been ground with stones containing a considerable portion of carbonate of lime; this being mixed with the flint, and eventually with the ware itself, rendered it fusible at a lower heat than usual, so that several ovens full of ware were fused down before the error was discovered.

When the flints are sufficiently ground in the flint-pan, the creamy mixture is transferred to another vat containing a considerable quantity of water. This vat is also furnished with an upright shaft and arms, by the revolution of which the finer particles of flint are kept suspended while the larger and heavier particles sink to the bottom. The water containing the

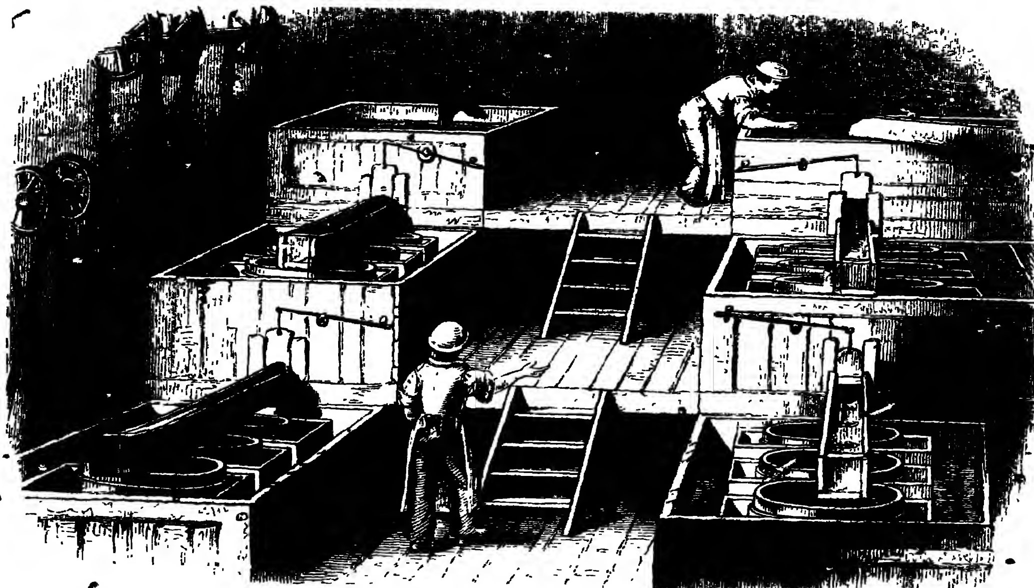


finer particles is then drawn off into a reservoir, and when the fine powder has subsided the water is allowed to flow off. The flint powder is considered as fit for mixing with the clay when a wine pint of it weighs thirty-two ounces, while an equal bulk of the diluted clay should weigh twenty-four ounces. By thus taking the densities of the two principal ingredients, the manufacturer is enabled to mix them in the proportions which he judges best adapted to the kind of ware intended to be made; but in this respect the practice of manufacturers, as already stated, varies considerably.

MIXING THE MATERIALS.

The clay and the flint being thus reduced to a state of minute division, are mixed in the proper proportions and intimately united by agitation. The mixture is then passed through sieves of hard-spun silk, manufactured expressly for the purpose. These sieves go on increasing in fineness, so as to prevent any unbroken pieces from remaining in the mixture, and to reduce the whole to a state of the utmost uniformity and smoothness. These sieves are arranged on different levels, as shown in the engraving on the next page, and are so connected with the machinery as to receive a sort of jogging motion, whereby the mixture passes freely through.

The fluid mixture of clay and flint is technically called *slip*, and as the water which has been so profusely employed in its preparation is, as it were, a sort of tool useful in the production of a result, but which may be laid aside when the result is accomplished, so now it becomes necessary to get rid of most of the water, and to bring the mixture of clay and flint to a doughy consistence for the use of the potter. As heat is the most convenient agent for getting rid of water, the slip is conveyed to the *slip-house* and boiled in the *slip-kiln*. The slip-house is a long low building, standing by itself, the tiles of the roof being placed half-way apart to allow of the more ready escape of steam and vapour. The slip-kiln consists of long brick troughs with flues under them of sufficient size to heat the mixture to the boiling point. It is necessary to keep the mixture constantly agitated during the early part of the evaporation, to prevent the heavier flint from subsiding; if this were not done, one part of the clay would contain too little and another part too much flint. There is, also, a tendency on the part of flint and clay, when water is



MIXING THE INGREDIENTS

present, to form a sort of mortar which speedily hardens, but this is prevented by diligent stirring. When

SLIP-KILNS

bubbles of steam cease to be formed on the surface of the slip, and portions cut out from different parts of the mass appear to be of the same texture and sufficiently hard, the fire is lowered, and the mass quickly removed to another part of the slip-house, where it undergoes the process of wedging.. The slip is generally in the kiln twenty-four hours.

The mixture of clay and flint after it has left the kiln ought to be kept for a considerable time, in order that the materials may become more intimately united than they ever can be by mere mechanical force. In China it is not uncommon for the prepared clay to remain fourteen or twenty years before it is thought to be in a fit state for use; and Mr. Parkes states that in some districts it is customary for a father to prepare as much porcelain clay as will be sufficient for the use of his son throughout the whole period of his life. In England, however, this point is not sufficiently attended to, although every manufacturer is aware of its importance; want of room, of time, and

often of capital, occasions it to be sometimes used warm from the slip-kiln, and not uncommonly when it has been lying for only a few hours or days.

The heat to which the mixture of clay and flint is exposed in the slip-kiln drives off the greater portion of the water in the form of steam, as already stated. As the evaporation proceeds, and the mass increases in density, the expansion of the water into steam fills the clay with little vesicles, which must be got rid of, together with any air bubbles entangled with the clay, for, if allowed to remain, they would form blisters or warts in the ware. This is accomplished in a remarkable manner. The mass from the kiln, extending many yards in length, is cut up into wedges by means of a sort of spade, and these wedges are turned over and dashed against each other. In this way the pile is worked two or three times in the course of a few months, during which the whole mass becomes more uniform, of finer grain, and not so liable to crack or become disfigured in the baking as the ware made with more recently formed paste.

This process, which is called *wedging*, is not however sufficient to get rid of air bubbles, nor to impart to the paste sufficient uniformity and smoothness. It has to undergo a more refined and elaborate process called *slapping*.

The workman called the *slapper* takes a mass of the paste, weighing from sixty to seventy pounds, and dashes it down upon a bench before him. He then cuts off a portion by drawing through it a wire furnished with a handle at each extremity, and taking up the piece thus separated he turns it over and dashes it down with all his strength upon the remainder of the mass. The wire is passed through a second time in another part of the lump, and the divided portion is again taken up and dashed forcibly down. This operation is repeated forty or fifty times, during which every portion of the clay is in turn brought to the surface, care being taken to preserve the *grain* of

the paste; that is, the layers are slapped parallel to each other, and not at right angles or obliquely, for if this were done the various segments would not reunite in the slapping, and the ware would be liable to fall apart in the baking.

In preparing the paste for the potter, it is usual to mix with it portions of paste produced by the process of *turning*, hereafter to be noticed, as, also, any vessels which have been accidentally spoiled previous to baking. This material is generally of a different colour to the paste now under notice, and it is curious to notice how perfectly the operation of slapping blends the whole into one uniform mass; two masses of clay of different colours being thereby formed into one mass of a colour intermediate between the two. Air bubbles are also effectually got rid of by this process, and the paste is thus prepared for being fashioned into some of the endless variety of useful and ornamental articles in earthenware.

In the preparation of paste for the manufacture of porcelain, the China clay of Cornwall is used in combination with ground flint and felspar; to this is added a considerable proportion of calcined bones, (which are supposed to improve the transparency of the ware,) and a small quantity of gypsum or sulphate of lime. Fragments of broken porcelain ground to a fine powder sometimes enter into the composition; and should this material not be at hand, small slips of it are prepared from clay, flint and gypsum, the two latter ingredients being in excess; these slips are baked into porcelain and then broken up and ground to powder for mixing with the other materials. Different writers mention other ingredients, such as a frit composed of nitre, soda, alum and selenite, together with a large admixture of ferruginous sand and a small quantity of common salt.

THROWING.

Articles in earthenware are brought first into shape by one of three different processes, named *throwing, pressing* and *casting*. Of these, throwing is the most ancient as well as remarkable, for by it vessels of elegant and beautiful forms are produced by the hands of the potter with such precision and rapidity as may well excite the admiration of the spectator. In pressing and casting the clay receives its form from plaster-of-paris moulds, and the articles are produced without any remarkable degree of skill on the part of the workman.

The thrower performs his work with the assistance of the ancient potter's wheel or lathe, consisting of an upright shaft about the height of a common table, on the top of which is fixed a disk of wood of sufficient diameter to support the largest vessel that is made. The lower end of the shaft is pointed, and runs in a conical step, and the upper part in a socket a little below the circular board. The shaft has a pulley fixed upon it with grooves for three degrees of speed, over which an endless band passes from a fly-wheel, by the revolution of which any degree of speed may be given to the shaft and its top-board. When this wheel is small, it may be placed alongside, as in the turner's lathe, and it is then driven by a treadle and crank: but when of large dimensions, by the arms of an assistant.

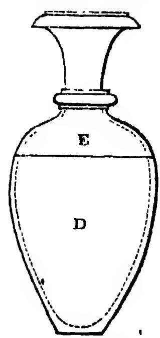
The mass of dough to be thrown is accurately adjusted to the size of the vessel required, for which purpose the mass as it is received from the slapper is cut up into portions with a brass wire; each portion is weighed separately, well slapped between the hands to expel water and air bubbles, and then rolled

up into a ball. This is usually done by a second female assistant, called the *baller*. The thrower, seated with one foot on each side of the wheel-head, with his elbows supported on his knees when his hands require to be kept steady, takes one of these balls, dashes it down upon the centre of the revolving board, and with both hands previously wetted, and occasionally dipped into water near him, he squeezes up the clay into a high conical column, and again forces it down into a lump, so as to get rid of any remaining air bubbles. With one hand or finger

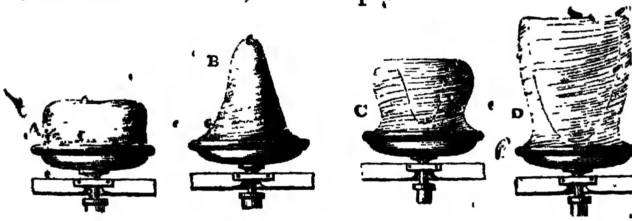
THROWING

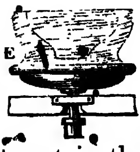
and thumb in the mass, and the other on the outside, or with his fingers only, he gives the first rude form to the vessel, and with a piece of horn, slate, or porcelain, called a *rib*, which has the profile of the shape of the vessel, he smooths the inner surface, gives it the proper shape, and removes the inequalities left by the fingers. In the mean time, the assistant keeps the wheel in constant motion, varying, however, the degree of velocity, according to the directions of the thrower, who requires different degrees of speed

at the different stages of his work. In order to make a number of vessels of exactly the same size, he does not rely entirely upon his eye; he is furnished with a very simple kind of guage, consisting of a peg or stick, placed opposite to him, at a certain distance from the centre of the vessel, whereby he is able to judge of the required height and diameter of the vessel which is being formed. It is scarcely necessary to remark that the thrower produces only such vessels as are circular, such as tea-cups, basins, &c. Handles, spouts, and ornaments, when required, are added afterwards. As fast as the thrower has completed one vessel to his satisfaction, he cuts it off at the base by means of a fine brass wire; the baller then hands him another ball, and dexterously lifts off the vessel, (which is now said to be in its *green state,*) places it on a board, and when a sufficient number are collected, they are removed in fine weather to the open air, and in moist weather to a warm room, where they gradually part with moisture, and are fit for the next process, which is *turning.*



The following figures will further assist the above description of throwing. In order to form the lower part of the vase D, the thrower dashes upon his wheel the lump of clay, A; this is worked into the conical mass B; then into the rude cup, C, and lastly into D. It is the business of the turner to reduce the thickness of the mass, and to improve





the shape. E, on the wheel, is intended for a portion of the cover of the vase. It will be observed that in all the figures on the wheel, a *spiral grain* is given to the clay, which is found best to retain the form given to the plastic material.

TURNING.

The operation of turning precisely resembles that by which wood, ivory, metal, and other substances are formed into articles with circular surfaces; and it is a curious sight to watch a rude clay cup or bowl spinning quickly round in the turner's lathe, with long and broad shavings flying off from it, under the operation of a chisel and other cutting tools. The thrower not being able to form vessels sufficiently thin, or to produce that finish and polish which are expected in articles of this kind, renders the process of turning one of considerable importance. "It requires considerable dexterity in the workman, to avoid destroying or fracturing the vessels, while forming them to their requisite size, thickness, and correct shape of circular vessels; and it presents numerous opportunities for the exercise of skill, taste, and genius, in giving to the several parts the rings and rims required, and to the whole all the elegance suggested by the pattern, and the little niceties, either with much difficulty, or by no effort, obtainable when on the throwing engine."*

In order that the turner may stand quite steady to his work, motion is given to his lathe by an assistant, called the *treader*. This is often done by a female; and as her right foot only is employed during the

* Encyclopædia Metropolitana.

turning, she is able to attend to the green vessels on the board, moistening their upper edges, and clearing away whatever may interfere with the turning. "The position of the turner while employed on earthenware is the reverse of that of the wood-turner; for instead of standing exactly linear with his lathe, or aslant a little from the head-stock, he looks towards this, and remains at entire freedom from every thing that might render him unsteady. On the chuck is a clay ring, kept scarcely moist. The vessel to be turned is put on the chuck, and as soon as the treader gives motion to the spindle, the turner presses with his tool or finger the upper edge, already moistened, into the clay ring. Next placing his tool opposite the tranverse axe of the piece, he carefully cuts away all surplus clay left by the thrower, and reduces it to the precise thickness required. In very valuable articles the turner weighs each vessel. The ornamental portions are formed, and when engaged in *engine turning*, while the spindle is in slow motion, the back spring causes the incisions of the circular plate or movement to bring the vessel nearer to the tool, and those parts are in consequence cut away in diamonds, dice, or other fanciful indenting; and the full part carries it away again, so as to form these dice, &c., at distinct distances all round the vessel. When all the cutting away of the clay has been completed, the treader very expertly gives to the spindle a retrograde motion, during which the turner applies the flat surface of a broad tool on the upper part of the vessel, and by gentle pressure thereon, gives to the whole vessel a solidity not previously existing, and a glossy smoothness of surface, removing all inequalities of surface left by the prior manipulations. The vessel is next cut loose from the clay ring, and placed on a board, for the handler, or to dry for the biscuit oven."

Handles, spouts, and other additions are attached to the articles by means of slip, which unites them

perfectly in a very short time. The superfluous clay about the handle is scraped off with a knife, and the vessel cleaned with a damp sponge, which gives it a uniform appearance. The clay for the handles, &c., is first formed into pipes at a small press, which forces the clay through a metal tube of the required size and form. This clay pipe is then cut up into lengths, and bent into the required shape, for a handle, &c. Spouts are formed by inserting a pin of the proper size into the metal tube, and forcing the clay between the two. Ornamental handles, spouts, &c. are formed by pressing clay into plaster-of-paris or steel moulds; figures of animals,

foliage, &c., are similarly formed, and are afterwards attached to the vessel by means of slip. In some cases copper moulds are used, smeared with oil, to cause the ornament to deliver itself freely. Flowers and foliage, &c. are also formed by hand with considerable dexterity and attention to botanical character; as the writer had an opportunity of witnessing a few months ago at the celebrated porcelain works at Meissen, near Dresden.

PRESSING.

The second method of forming articles in earthenware is by *pressing*, which is the same in principle, only on a larger scale, as the method just alluded to of forming ornaments in plaster moulds. Plates and

dishes are made by this method, so that this forms a very important department of the manufacture.

The plaster moulds used in pressing are exceedingly numerous; a complete set being required for every new pattern, and for every size of the same pattern. Plaster-of-paris, gypsum, or sulphate of lime (the same substance under three different names), possesses the useful property, when recently burnt, of combining with water so as to form a smooth, hard kind of mortar. When received at the manufactory in its crude state, it is ground between a pair of stones in a mill, similar to that used for grinding corn. This powder is next heated in a kiln, where it parts with a large quantity of moisture; this is called *boiling;* and when the process is complete, the powder is called *boiled plaster.*

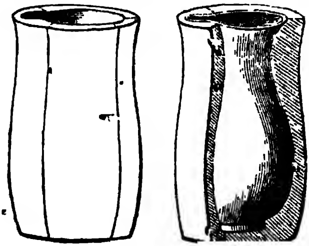
A model of the article required to be executed being prepared, it is placed on a board of the proper size, and at the distance of the intended thickness of the mould, a *cottle,* or bat of clay is fixed. A portion of the model is also covered with clay, and the exposed portion is brushed over with a wash formed by boiling a solution of potash, soft-soap, and china clay; this is to prevent the plaster from sticking to the model, and also to impart to the mould the requisite smoothness.

A quantity of boiled plaster being quickly mixed with water, is poured, while still fluid, around and over the model, till the proper thickness is attained. Considerable heat is given out during the combination of the water and the plaster, but in a very few minutes the plaster is sufficiently *set* to bear removal. The clay cottle is then taken away, the other parts of the model are covered with plaster, and the mould is thus completed. In a few hours it is taken apart, and the model removed, when the mould presents an accurate impression of the model in all its minute details. When the mould is properly dried, it is fit for use.

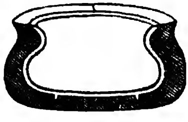
Moulds for plates and dishes, and similar shallow articles, consist of only one piece, and are formed by taking the impression of the upper surface of the model of the plate, &c. in plaster; the plate-maker placing the mould upon a *whirler*, formed of a thick block of plaster turning freely round, takes a ball of clay of the proper weight, and flattens it out with a block of plaster with a broad base, called a *batter*. When a large mass of paste is required, as for a large dish, a moistened sheep-skin is spread on a marble table, and over this the paste is extended with a rolling-pin, supported on two guide rules. The extended paste is then lifted up upon the skin, which prevents it from falling to pieces, and being placed upon the mould, the skin is removed. The workman then proceeds to work the paste down upon the mould, pressing out the air with a small slab of baked porcelain, then smoothing and adjusting it with a piece of flexible horn, thirdly, rubbing it well with a wet sponge, and, lastly, with wet leather. The edges then being trimmed, and the maker's name, or other inscription or mark stamped upon the back, a boy takes up the mould with the plate upon it, and conveys it to a room, raised to a high temperature by means of warm air conducted through it in an iron pipe. A series of wooden shelves are ranged round this room, upon which the moulds are placed. In about two hours the plate is sufficiently dry to be removed from the mould, and the mould, which has absorbed a large portion of moisture from the paste in contact with it, is unfit to be used again immediately; but, by keeping a number of moulds in use, those first used are sufficiently dry to be employed again, and each mould can thus be used five or six times in a day. A man, with the assistance of a boy, will make 400 or 500 plates in a day.

Such is the simplest form of pressing. Deep vessels, such as ewers, vases, &c., are formed by

what is called *hollow ware pressing*, or *squeezing*, for which purpose the mould is generally made in four parts, accurately fitting together. The presser pre-



pares for his work by getting ready a number of crusts of clay, called *bats*, of the proper size and thickness for pressing into the separate parts of the mould. From a properly-slapped mass of clay and flint before him, he cuts off with a brass wire a piece of the proper size, which he kneads between his hands into a ball, and then dashes it down upon the bench before him; he then beats it out, with a plaster batter, to the required thickness and shape, and puts it aside for future use. When a sufficient number of bats is collected, the mould, or a section thereof, is put upon a whirler, and one of the bats is *bossed*, or forced into it with a moist sponge. The clay is also forced into all the parts and corners of the mould by



working it about with the thumbs. When all the sections of the mould are thus filled, and the surface smoothed with a moist sponge, the edges are trimmed with a sharp knife, and moistened with slip; the parts of the mould are next carefully brought together, and secured by a strap passed round them. The presser then passes his finger up every joint, so as to form a channel into which a thin roll of clay is inserted, which is worked in first by the finger and

thumb, and then smoothed with moist leather, or a cow's lip, on account of its convenient form. All

HOLLOW WARE PRESSING.

marks are carefully removed with a moist sponge, and the inside is then washed with pure water. The mould is next set aside for a short time to dry, and is again placed on the whirler, and polished with a flexible plate of horn. The mould is then placed in a warm room, and, when sufficiently dry, the article is taken out to be *fettled*, or trimmed with proper tools, so as to get rid of any appearance of seams; superfluous portions of clay are removed, and the exterior surface is then cleaned and polished with a moist sponge; the handles, and other appendages, are added; it is, lastly, polished with the horn, and is then set aside to dry previous to baking.

In some establishments where original articles of great taste and beauty are produced, models in clay must first be formed by an experienced modeller, who is generally an artist of considerable skill. When the design is elaborate, the mould is of course complicated. The writer saw at Meissen models for four vases, emblematical of the ancient elements—fire, air, earth, and water, the moulds for which consisted of

150 separate pieces. The impressions as delivered from the moulds are put together by means of slip, and any little ornaments, such as flowers, foliage, &c. which are made by hand, are attached by the same material.

Where the ornaments are of a simple character, the articles are formed by the union of throwing and moulding; as for example, coffee cups with a raised ornament in the inner rim, which were being made at the time of the writer's visit to Minton's porcelain works. Each cup was first formed by throwing; it was then put over a mould to receive the interior ornamental border; the throwing was next repeated, or as it is now called *laying*, the object of which was to bring the paste close up to the surface of the mould; by this method the inside of the cup is finished; the outside being afterwards brought into proper shape, and the cup made thin and light by turning. When embossed ornaments are on the outside of the vessel, the reverse of the above process is adopted, the paste being put into the mould while the inside of the vessel is formed by throwing. Scolloped edges are sometimes produced by the turner, but more usually they are formed by hand with a knife.

CASTING.

In forming delicate fragile articles intended for ornament rather than use, the process of *casting* is often adopted. For this purpose the clay and flint are mixed with pure water to a creamy consistence, and in that state poured into the moulds. The plaster quickly absorbs water from that portion which comes in contact with it, and hardens it sufficiently to allow of the central and still fluid portion being poured off. A coating of clay is thus left attached to the mould, and being left to dry for a short time a second portion of clay is poured in; this, how-

ever, is thicker than the first charge, and serves to strengthen and support the thin layer already adhering to the mould: the fluid portion being poured off, the mould with its contents is placed in a stove until sufficiently dry to be separated. The cast is then taken out, and while yet in its green state it is carefully examined by the modeller, and any little defects corrected. By this method are formed the porcelain statuettes now so common. The lace which adorns many of the female figures, is put on together with other minute ornaments after the figures are taken out of the mould. The lace is formed of cotton thread, manufactured for the purpose; and this being dipped into slip, imbibes a sufficient quantity of the porcelain material to take the place of the thread; so that when the latter is destroyed by the heat of the furnace in baking, the lace appears as if it had been originally formed of real porcelain.

BAKING THE BISCUIT WARE.

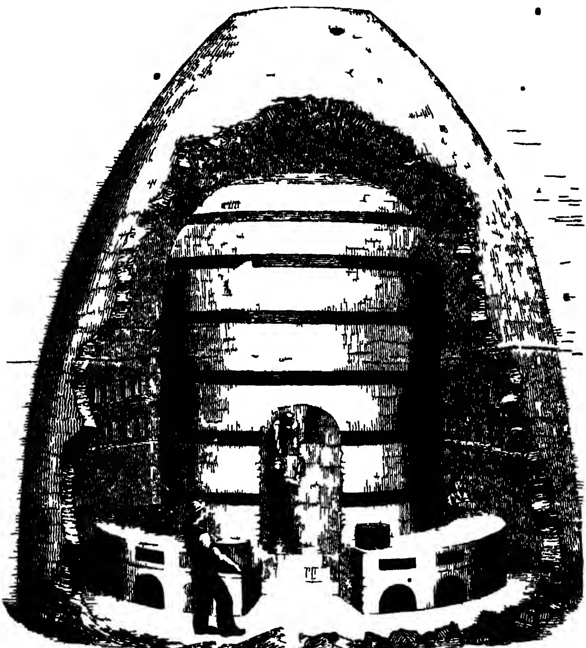
The articles produced by any of the processes already described are kept in a heated room until they have parted with much of their moisture. In the course of drying they gradually assume the colour of the dried plaster of a new wall, and when the overseer pronounces them to be fit for the kiln they are packed in coarse strong vessels called *seggars*, for the purpose of protecting them from the direct action of the fire and the products of combustion, which would soil and otherwise injure them. Most of the seggars are oval in shape, and greatly resemble a lady's band-box without the cover; the usual dimensions are two and a half by two feet, and twelve inches deep:—those used for plates are cylindrical, and vary in depth from eight to fourteen inches; the usual dimensions of the oval vessels are twenty-two and fifteen inches. The seggars are made of the marl which is found in such abundance in the Staf-

fordshire collieries; it consists of grey siliceous shale and carbonaceous schist. It is prepared for use by exposure to the weather, and when reduced to powder is mixed with old ground seggars. The clay thus produced is well kneaded, rolled out into shape, and the seggar is formed by folding the clay over a hollow wooden mould. The seggars require careful drying and firing before they are fit for use.

In filling the seggars, the pieces are prevented from sticking together by interposing between them a quantity of sand or powdered flint. Many articles in soft porcelain are firmly imbedded in dry flint powder, which gives them support and prevents them from warping in baking. Saucers are kept in form by an earthenware ring, called a *saucer setter ring;* cups have an earthenware ring on the top of each, and are not allowed to touch each other in the seggar. As the seggars are filled they are conveyed to the furnace, and are piled up one over another, the flat bottom of one seggar serving as a cover to the one immediately below it. They are separated however by a roll of clay on the rim of each seggar; each pile of seggars as it stands is called a *bung.* Considerable skill is required in arranging the seggars in the oven, in order that the various articles may receive the required amount of heat. The largest and coarsest pieces are usually placed on the floor of the oven. About thirty thousand pieces of ware are usually included in one baking.

An accurate idea of the appearance of the oven or kiln may be formed from the engraving on the next page, which represents the kiln before the fire is applied, and while the seggars are being arranged in it. A portion of the outer cone of brick-work, or *hovel,* is removed in order to show the interior arrangements. The kiln itself is a massive cylinder of brick-work, bound with iron bands, and surmounted by a dome, with an aperture in the top to allow of the exit of smoke; this hole is situated immediately under the

chimney of the hovel. The kiln is surrounded by a number of fires and flues skilfully arranged for producing a high and equable temperature within. The use of the hovel is to protect the kiln from the cooling effect of air and rain, and to furnish a chimney to the kiln. On shelves running round it are ar-



BISCUIT KILN

ranged seggars in a green state, where they are dried previously to baking. When the kiln is filled with seggars the doorway is carefully bricked up, the fires are lighted, and from that time till the baking is completed, (a period of from thirty-three to forty hours for porcelain, and from forty to forty-eight hours for flint-ware,) the kiln is anxiously watched by experienced

workmen. The heat employed should be just sufficient to drive off the moisture and agglutinate the particles which compose the ware. It should never be sufficient to fuse them; for if this were done, there would be danger of their breaking down and becoming spoiled.

The fires are usually lighted at six o'clock in the evening from a supply of burning coals outside the hovel prepared some time before. In the course of three or four hours the fires have gained considerable force, and the flame ascends completely through the cylinder into the chimney of the hovel. Coals are added from time to time, and the draft properly regulated. In the course of the night the flames may be seen issuing from the chimney. Early in the morning the fireman takes out his *first watch* to see how the baking goes on.

*These watches or trial pieces are rings made of Staf*fordshire fire-clay, which has the property of assuming different shades of colour at different temperatures. A number of these are placed in a seggar opposite a hole in the cylinder, and the fireman, removing the clay stopple from this hole, inserts a long iron rod, passes the end of it through one of the rings, and withdraws it. When it is cool he is able to judge of the heat of the kiln, and the consequent state of the ware in the seggars by the appearance of the ring, and he increases or lowers the temperature accordingly. When by frequent inspection of the trial pieces the baking has been judged sufficient, the firing is discontinued, the furnace and ash-pit doors are closed, the fire is allowed to go out, and the contents of the oven are then left to cool gradually during twenty-four or thirty hours. In the course of one baking the kiln consumes about fourteen tons of coal, of which four are put in the first day, seven the next day and following night, and the last four to give the strong finishing heat."

When the ware is removed from the kiln it is in the state called *biscuit*, not because it has been *twice*

cooked or baked, as the name implies, but from its resemblance, both to the eye and to the touch, to the dry and rough surface of well baked ship-bread.

Some articles, such as wine coolers, butter coolers, and water bottles used in the East called *alcarrazas*, are finished when brought to the state of biscuit. Water contained in these vessels slowly oozes through the substance of the ware and forms a dew on the outside, the evaporation of which carries off so much heat as to reduce the temperature of the remaining liquid many degrees below that of the atmosphere. This effect is proportionally increased by suspending the porous vessel in a current of air; as, for example, between two doors; the current carrying off the dew much more quickly than in a still atmosphere.

When the ware is removed from the oven it is *carefully taken out of the seggars, placed in baskets,* and conveyed to the biscuit-room, where each article is examined, and struck with a piece of wood, its sound indicating whether the baking has been properly conducted. Considerable shrinkage has taken place in the ware, in consequence of the high temperature to which it has been exposed; for it is a curious property of clay to contract, not to expand by heat, as most other bodies do; not that there is, in fact, any peculiarity in this respect as regards clay, but it retains its moisture so obstinately that a very great heat is required to get rid of it, and the shrinkage is occasioned by the passing off of moisture, and the consequent contraction of the clay. When this is got rid of, the clay expands, like all other solid bodies, by heat; but while at a high temperature a more intimate union takes place between the clay and the flint and other ingredients of the ware, so that when cooled again and moistened, the ware does not return to the dimensions which it had in the green state. Hence, in making articles to pattern, it is necessary in the first instance to make them larger than the model, in order to allow for shrinkage.

GLAZING BISCUIT WARE.

Such articles as are pronounced perfect in their biscuit state are ready for glazing; but if the ware is to be covered with any design or ornament, this is first added by printing, or painting by hand, in enamel colours, as will be described presently. White and cream-coloured wares require only a coating of glaze to fit them for the market.

There are various kinds of glazes, all of which possess the property of melting into a glass, so as to cover and completely protect, the porous fragile biscuit ware, rendering it impermeable to water and other fluids, improving its appearance, and preventing it from crumbling and decomposing by use, and by exposure to the air.

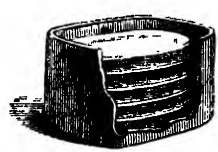
The composition of glaze is another of the secrets of this art, each manufacturer having his own recipes for glazes; they generally contain flint, and an alkali, the usual ingredients of glass, with sufficient lead to render them fluid. They are applied either in the *raw* or the *fritted* state. In the one case the ingredients are reduced to powder, mixed up with water to a creamy consistence, and then brushed over the biscuit. In the other case the ingredients are melted or fritted in a furnace, which ensures their chemical combination; a semi-transparent glass or enamel is thus produced, which is then reduced to powder, and applied in the same manner as raw glaze.

There are three principal glazes; one for the common pipe-clay, or cream-coloured ware; a second for the finer pipe-clay ware, to receive impressions,—this is called the *printing body;* a third for the ware which is to be ornamented by painting with the pencil. According to Dr. Ure, the glaze of the first or common ware is composed of fifty-three parts of white lead, sixteen of Cornish stone, twelve of flints, and four of flint or crystal glass; or of forty of white

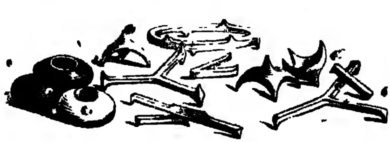
lead, thirty-six of Cornish stone, twelve of flints, and four of flint glass. These ingredients are applied raw. The glazes intended to cover all kinds of figures printed in metallic colours, consist of twenty-six parts of white felspar, fritted with six parts of soda, two of nitre, and one of borax; to twenty pounds of this frit, twenty-six parts of felspar, twenty of white lead, six of ground flints, four of chalk, one of oxide of tin, and a small quantity of oxide of cobalt, to take off the brown cast, and give a faint azure tint, are added. The stone ware which is be painted is covered with a glaze composed of thirteen parts of the printing colour frit, to which are added fifty parts of red lead, forty of white lead, and twelve of flint, the whole having been ground together. It is stated that these compositions produce a very hard glaze, which preserves for an indefinite time the glassy lustre, is not subject to crack and exfoliate, cannot be scratched by the knife, is not acted on by vegetable acids, and does no injury to articles of food kept in contact with it. There is, however, an objection to the use of lead in glazes, not only on account of the injury to the health of the workmen, especially when raw glazes are employed, but from the liability of the lead to become soluble in acids, and to mingle with food, whatever may be said to the contrary. Hence the use of lead in glazes is becoming much less common. At Messrs. Ridgwood's the writer saw a large quantity of glaze flowing from the fritting-furnace, in the composition of which not a particle of lead had been employed.

The fritted glaze having been ground to a fine powder, is put into the *mixing-tub*, where the other ingredients are added. The whole being well worked together with water, the mixture is drawn off into a *dipping-tub*, in which a quantity of common salt is sometimes added to make the water more buoyant, and thus to prevent the metallic oxides of the glaze from subsiding.

The articles in the biscuit state being carefully brushed from dust or powdered flint, are immersed one by one in the glaze-tub; as each article is taken out, the *dipper* skilfully shifts it into different positions, so as to distribute the glaze powder uniformly over the surface, and to prevent it from being thicker in one part than in another. While this is being done the watery particles of the glaze are absorbed by the porous biscuit, leaving the surfaces covered with a thin coating of white powder; the article is then set aside to drain, either upon a hair sieve, or upon a board containing rows of projecting points. When sufficiently dry, the glaze has very much the appearance of a uniform coat of whitewash, entirely concealing the biscuit, together with any figures which may have been previously printed or painted upon it. The articles are again carefully packed in seggars, and various arrangements are made to prevent them from sticking together. It is obvious that a layer of sand or flint cannot be used for the purpose, as in the biscuit oven, since the glaze in melting into a glass would unite with the sand or flint. On the inside of the cylindrical seggars strips of seggar clay are fixed, prepared with triangular holes in which *stilts* of clay are inserted in order to support the pieces of ware and keep them separate during the baking. Other articles of pottery are separated by various forms of rests and supports called *cockspurs, stilts, triangles,* &c. The seggars are



SEGGAR



WATCHES, COCKSPURS, TRIANGLES, AND STILTS.

then conveyed to the *glaze-kiln*, which is similar in its arrangements to the biscuit-kiln, but of smaller dimensions. The heat employed is just sufficient to fuse the glaze into a transparent glass, and to enable it to unite perfectly with the surfaces of the biscuit. Rings of clay covered with glaze (as shown in the figure,) are drawn out from time to time, whereby the workman ascertains the state of the furnace.

PRINTING ON BISCUIT-WARE.

When the ware is to be ornamented with a pattern, this is generally added before the glazing. The blue of the common dinner-service is produced by means of oxide of cobalt, mixed with ground flints and sulphate of baryta, in certain proportions, according to the shade required. These materials are fritted and ground, and before being used they are mixed with a flux, consisting of ground flint and thick glass powder, which serves to fix the colour upon the biscuit, and to prevent the glaze from displacing the lines of the pattern. The colour thus prepared is then mixed with linseed-oil previously boiled to the consistence of honey, resin, tar, and oil of amber, forming altogether a very viscid kind of printer's ink, which is liquefied for use by spreading it out upon a hot iron plate.

The pattern is engraved upon copper plates, in the usual way for copper-plate printing. The printer covers the engraved surface of the plate (previously made hot at a stove,) with the colour prepared as above; this he does with a leathern muller, and then scrapes off the superfluous colour with a pallet-knife, and lastly cleaning it with a dossil filled with bran. The lines representing the pattern, which are cut rather deeply, will thus be charged with ink, while the smooth, unengraved portions of the plate will be clean. The pressman then takes a sheet of thin

yellow unsized paper, intended to receive the impression, dips it into soapy water, and lays it moist upon the copper-plate. The plate is then passed through a cylinder press, and the paper receives the impression of the pattern. The soap enables the paper to come off more readily from the copper; and when they are separated, the paper is handed to a little girl, named the *cutter*, who cuts the pattern into its separate parts, clears away white unprinted paper from about them, and places them by the side of the woman called the *transferrer*, whose business it is to transfer the pattern from the paper to the bis-

PRINTING STONE WARE.

cuit. Taking a biscuit article, she places the several sections of the pattern, with the inked part downwards, in their proper places, and then rubs them in with a roll of flannel firmly tied up into a rubber, one end resting against the hollow of the right arm-pit, and the other upon the biscuit. At first she rubs

gently, but afterwards more forcibly, until the ink is fairly transferred from the pattern to the surface of the ware. When a number of articles are thus treated, they are placed in a tub of water, and gently washed with a brush to get rid of the paper.

The articles thus prepared are placed in an oven for a few hours, and subjected to a heat sufficient to drive off the oily particles of the ink, and the water imbibed during the washing. The ware is then covered with a glaze, which completely conceals the pattern, but which in the glaze-kiln melts into a transparent glaze, completely protecting the pattern but leaving it perfectly distinct.

At Minton's porcelain-works another method is adopted for transferring the design to the surface of the ware after glazing. A flexible sheet of glue, called a *paper*, or *bat*, being placed upon a flannel, the engraved plate, charged with oil, is brought down upon it, and gently pressed by hand, when the glue receives an impression of the pattern, which is thence transferred to the surface of the biscuit; being carefully taken off, it is applied to a second vessel, and communicates a second impression. The glue-paper is then cleaned with a wet sponge, and left to dry while other papers are in use. The colour, which is in the form of dry powder, is then dusted over the vessel, and it adheres only to those parts which have received the impression in oil. When the vessels thus treated are put into the oven, the oil is driven off by the heat, while the colour sinks in and becomes indelibly incorporated with the glaze.

PAINTING AND ORNAMENTING THE WARE.

Earthenware and porcelain are ornamented with various degrees of skill, by artists who lay on the colours with a camel's-hair pencil. The colours are

all metallic oxides, and are ground up with certain substances which vitrify by heat, such as glass, nitre, and borax, in certain proportions. By means of this flux the colours are permanently fixed upon the ware, and are protected from the action of the air and other agencies capable of affecting them. The colours used in painting tender porcelain are those employed for painting in enamel, which is a kind of glass made opaque by oxide of tin, and rendered fusible by oxide of lead. Painting on tender porcelain requires to be several times retouched with the pencil, in order to give it the brilliancy and distinctness obtained by the use of the same colours on hard porcelain, the compact nature of which generally renders these retouchings unnecessary, "except for the most elaborate specimens of the art, which can by such means, however, be produced with the most admirable degree of perfection, so as to render paintings on porcelain not distinguishable from the first productions of the pictorial art, without reference to the body upon which it is performed, or to the means used for bringing out the colours; natural objects, landscapes, portraits, and even historical pictures, being represented with all the truth as well as with all the brilliancy of colouring which distinguish the works of the first masters."*

It would be useless to transfer to the pages of a work of this kind the various recipes which have been given for coloured enamels and glazes, not only because the reader is not likely to be interested in such details, but also because, in many works, the recipes seem to have been given as much with the view to mislead as to guide. The old artists, who succeeded in producing fine colours on glass and porcelain, kept their processes secret, and when called upon to publish them, did not scruple to give false or insufficient directions. Even at the present day enamel painters keep the composition of their colours

* Porter—Cabinet Cyclopædia.

secret; so that in different houses similar results are obtained by slightly different means. It may, however, be interesting to mention what metals are employed for the production of different colours.

Purple and violet are obtained by dissolving gold in aqua regia, (a mixture of nitric and hydrochloric acids,) and immersing a bar of pure tin in the solution. By this means a precipitate is obtained, named after its inventor, the *purple precipitate of Cassius.* By dissolving the gold and the tin separately, and then mingling them in different proportions, various shades of carmine, violet, and purple are obtained. Other precipitates of gold are also made for the production of these colours.

Red oxide of iron also produces a red colour, of less brilliancy than that obtained from gold. Different proportions of the black and red oxides of iron furnish various shades of reddish brown, chestnut, &c. Oxide of iron calcined with double its weight of common salt, yields a permanent red colour.

Yellow colours are obtained from chromate of lead; also from white oxide of antimony mixed with sand and oxide of lead. A mixture of the oxides of uranium and lead produces a straw colour.

Blue is furnished by oxide of cobalt; a deep rich shade of this colour to a light blue, is obtained from different proportions of the oxides of tin and zinc.

The green oxide of copper is usually employed in the production of that colour. Various shades are obtained by different mixtures of Prussian blue and chromate of lead. Oxide of chromium also gives a beautiful green colour.

Oxide of manganese is used for black; but it is usual to unite several oxides to produce this colour. A pure white is produced from one part of virgin tin and two parts of common salt.

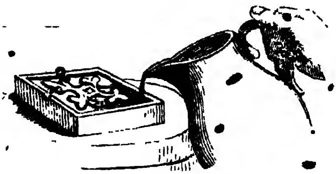
The colours, when required for use, are pounded in an agate, porcelain, or glass mortar, with a pestle of the same material as the mortar. They are then

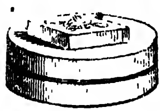
ground, with a small quantity of oil, on a glass palette firmly bedded in plaster on a wooden frame. The colours are rubbed until all roughness has disappeared. Oil of turpentine is the usual vehicle for the colour and the flux, the proportions of which are carefully weighed out and ground on the palette with the volatile oil. The mixture is made sufficiently fluid for the artist to produce his strokes with a camel's hair pencil with ease and distinctness. In painting the pattern, the artist is seated at a table from which projects a board for the support of his right arm, and he holds the article in his left, as shown in the figure. In many cases the colour, as applied with the pencil, is very different from its bright and resplendent appearance after the fire has driven off the oil and other matters, which cloud its beauty. It is difficult to imagine that the dark and dingy mixture which seems to disfigure the delicate surface of the porcelain, is capable of so complete a transformation.

PAINTING PORCELAIN

When the ware has been painted, the colours are dried, and the oil driven off in a furnace at a moderate heat. They are then glazed, and put into the glaze-kiln, or at once consigned to the enamelling-kiln, as the case may be. It is not necessary to follow this part of the subject further, as the general reader will obtain a sufficient idea of the various processes from the details already given.

The gold employed in gilding porcelain, is first dissolved in aqua regia; the acid being next driven off by heat, the gold remains in a minutely divided



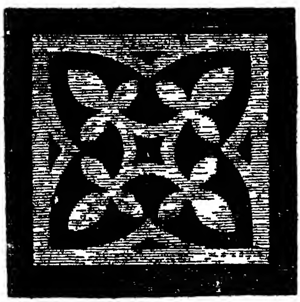


adhere. The filling up of the device is next performed in an ingenious manner. A quantity of slip or clay, in a semifluid state, is poured over the tile so as completely to conceal its surface; this is spread over with a knife, and then left for twenty-four hours, when the slip becomes tolerably hard. The tile is then placed on a small whirler, and the pattern and the ground are brought out by scraping away the superfluous clay, and leaving it only in the depression caused by the pattern mould. The whole is, lastly, made smooth,

PRESSING AND SCRAPING TILES.

and polished with a knife, and any little defects corrected; the edges are squared and their sharpness rounded off with sand paper; the tiles are then ready for the *green-house*, where they are arranged on shelves, and kept at a moderate heat for about seven days. After this period, the tiles are further dried in a *hot house*, at a good strong heat;

They are then arranged in seggars, and fired as baking pottery and porcelain, only about double the time is required for the purpose. The oven is let to cool gradually during about six days, and the tiles are then drawn in their finished state. These tiles contract in firing, about one eighth of an inch in every inch. The dry tiles contract about one sixteenth of an inch.

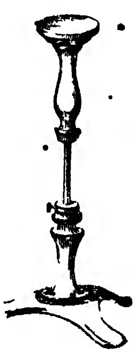


YELLOW ORNAMENT ON BLUE GROUND

WHITE ORNAMENT ON BLACK GROUND

R. CLAY, PRINTER, BREAD STREET HILL.

a th ..te, and being mixed with borax and gum-water, is var ..plied to the wares with the pencil. Articles which po... ..ve their edges, or other parts, ornamented with a grou..rcular line, are placed on a *whirler*, or circular head sl.p.. wood, capable of revolving on the top of a it ..llar. The pillar can be lengthened or short- ..ed, at pleasure, by means of an iron rod fi.. ..serted within it, and can be fixed to the re- sligh.. and.. of At fix.. inte.. dim.. and.. of t.. mo.. me..



quired height by means of a thumb-screw. The artist, seated in a chair, places this machine before him, and adjusts it the proper height: he keeps it steady by resting his feet on the claw at the bottom; and fixing the article to be ornamented upon the circular head, he applies the pencil to it with one hand, kept steady by means of a rest, then, with the other hand, he causes the circular head to revolve. In this way circles are described with great truth and readiness. When the articles thus ..namented are baked, the gold appears of a ding.. ..ue; but the beautiful lustre of this metal is brough.. ..ut by burnishing, first with agate, and then with ..lood-stone. This is done by a female, who rubs the burnisher lightly on the gilding, taking care not to cross her strokes, lest the gilding should appear scratched. The gilding is clean.. .. ..m time to time .. ..th a little vinegar or white lead, and to prevent the porcelain from b.. soiled, it is held with a piece of cl.. ..n linen. It was stated, some years

BURNISHING

P.. ..p..

ago, that the weekly consumption of gold for gilding porcelain, &c., in Stoke-upon-Trent borough, amounted to the value of £650 sterling, or £35,900 annually.

THE MANUFACTURE OF ENCAUSTIC TILES.

The revived taste for decoration with encaustic tiles has led to the invention of a number of ingenious processes for the production of these articles, with a facility and beauty of effect which were not capable of being attained by the ancient method. In comparing the old with the modern productions, it may perhaps be said that the former as much excelled the latter in beauty and variety of design, as the latter surpass the former in facility of production and excellent workmanship.

The following account of this branch of manufacture was obtained during a visit to the extensive tile and mosaic works of Messrs. Minton, of Stoke-upon Trent.

Encaustic tiles consist of a thickness of red clay, with a facing of a finer clay, which bears the coloured ornament or device. The bottom of each tile is also covered with a thin layer of clay, different from the body, in order to prevent warping during the drying and baking.

The body of the tile is formed of red clay or marl, obtained from Cobshurst, about four miles from Stoke. When dug out, it is left exposed to the air for about seven months. This is called *weathering* or *wintering*. When brought into the manufactory, it is thrown into a tank and worked about in water, with a blunger. When divided to a certain extent, it is laded into another tank, and blunged; this operation is repeated

a third time. It is then passed through sieves of various degrees of fineness, mixed with various compositions, and is then either dried into hard lumps and ground into powder at the mill, or evaporated at the slip kiln, according to one of two methods by which it is intended to be formed into tiles.

By Mr. Prosser's patent, the powder, as it comes from the mill, is placed on slabs of plaster-of-paris, slightly damped. It is then sifted through fine sieves, and, when subjected to intense pressure, the particles of the powder will unite into firm, solid, slabs or tiles. At the lower extremity of the screw of the press, is fixed a steel plate, of the size and pattern of the intended tile; this fits into a steel box of the same dimensions, the bottom surface of which is ribbed, and this, by impressing ribs upon the under surface of the tile, enables it to adhere more strongly to the mortar or cement in laying down the tiles for a pavement, or for covering a wall. A quantity of the

THE PRESS

powder being swept into this metal box, the steel plate is forced down upon it. In a large press, such

as that shown in the figure, the force exerted is equal to about four hundred tons; and a thickness of three inches of powder is compressed into a tile one inch thick, with sharp edges, and a beautiful polished surface. Tiles of various sizes and shapes are thus produced, the largest of which present a surface of forty two inches by nine inches; also such articles as tops for tables, eighteen inches in diameter, scale-plates for pork and butter-shops, twelve inches in diameter and upwards. Small ornamental buttons and shirt-studs, are made in a similar way at smaller presses; also tesseræ, for mosaic work of various shapes, colours, and sizes, forming, when put together, all the beautiful devices of which mosaic work is capable. When, however, the size of a tessera exceeds one and a half inches square, it becomes a tile. When these various articles leave the press, they are put into a hot room for a week or two, and are then ornamented, glazed, and fired.

Such is the method of forming what are called *dry tiles*. Encaustic tiles are formed from the clay after it has been evaporated in the slip kiln. It is wedged and slapped to get out the air, and then slapped into a block, of the form of a cube, or parallelopiped, and placed before the tile-maker, who cuts off and removes a square slab, by passing a wire through it: upon this, the facing of finer clay, coloured so as to form the *ground* of the tile, is batted out, and slapped down; it is then turned over, and a facing is applied to the bottom of the tile to prevent warping; the tile thus formed is next covered with a piece of felt, and put into a box-press: a plaster of Paris slab, containing the pattern in relief, is then brought down upon the face of the tile, and impresses in the soft clay or ground of the tile, the design which is afterwards to be filled up with clay of another colour. When the tile is removed from the press, the name of the maker is stamped on the back, together with a number of holes to make the mortar